THE CONSERVATION OF MARINE ANIMALS ON DUXBURY REEF

by

Gordon L. Chan & Alfonzo Molina

COLLEGE OF MARIN

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KENTFIELD, CALIFORNIA 94904

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A research team is composed of many integrated and important components. This 1969 Duxbury Report was compiled through the combined efforts of the following members. Each name is followed by the person's special area of research. These 1968 studies are kept as references at the Bolinas Marine Station (Appendix 4) for interested investigators.

Pamela Blair - - - - - - - - - Sea stars
Sara Conklin - - - - - - - - - Turban snails
Mary de Fremery - - - - - - - Marine algae
T.A. Gabrielson - - - - - - - Chitons
Terry Gosliner - - - - - - - - Sea slugs
Robert Hamilton - - - - - - - Sea anemones
Kit Hermann - - - - - - - - - Sea urchins
Buz Leuchtenberger - - - - - - Fishes
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William Murray - - - - - - - - Rock boring clams
Dennis Peters - - - - - - - - Rock boring clams
John Phillips - - - - - - - - Duxbury Reef surveying
James Smith - - - - - - - - - Fishes
Gary Williams - - - - - - - - Mussels
Diane Zimmerman - - - - - - - Sea urchins
Craig Hansen - - - - - - - - - (Marine Technician, BMS)

The contributions of the above individuals are much appreciated. The accuracy of the information in this report is based on the interpreted opinions and studies of these student investigators and the authors. I also wish to thank Dr. Stanley H. Weitzman who contributed his fish species list of Duxbury Reef (Appendix 3).

Special appreciation is directed to my co-worker, Mr. Al Molina, Director of the Bolinas Marine Station, who co-authored this report with me. Many of the personal experiences reflected in this paper (enclosed by quotation marks in the text) come from my own research on the reef since 1957.

G. L. Chan

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I. INTRODUCTION - Abstract

Question: What is so important about Duxbury Reef?

Compared to the magnitude of the world's social problems, Duxbury Reef does not seem to be of much significance. However, if one were to consider this reef in light of the intrinsic educational values to man, it then becomes very important. This report on the need to conserve the marine animals on Duxbury Reef intends to illuminate the historical problems of the reef area. The eventual major recommendation coming from this report is that man must declare this Duxbury Reef to be a "marine reserve", to benefit the present and future populations of Bay Area Californians.

> "The sea animals were very beautiful. Here was life from which we borrowed life and excitement" - John Steinbeck

The charm and attraction of this whole area may be seen by the aerial photograph on the cover of this report. The gigantic San Andreas fault along the right side of the photo seems to set apart the Bolinas Headlands and Pt. Reyes Peninsula as an island in time. To a visitor who may be oriented to the ocean landscape, the following is but a minute portion of the beauty surrounding this whole vicinity:

1. As one comes south down the Olema Valley, the San Andreas rift zone valley and the Bolinas Lagoon would be encountered. This lagoon is one of the few natural lagoons remaining in California where visitors may see unparalleled ecological lagoon habitats, flora marshlands, bird feeding grounds (Audubon), and a magnificent variety of marine invertebrates and vertebrates.[1] At the present time, this beautiful lagoon is being threatened by man's desire to turn this natural habitat into a large boat marina. Various forces of conservation groups in Marin County have banded together to thwart this proposed marina design. Would it be so wrong to allow the lagoon to remain and be preserved in its natural state as a marine refuge?
2. Just below Bolinas Lagoon is the Stinson Spit, a finger of collected beach sand forming the southern boundary of the lagoon. Unfortunately, this spit is dotted with man's creations - homes, telephone poles, tennis courts, etc.
3. Moving west from the Bolinas Lagoon and past the quaint community of Bolinas, one traverses across the uplifted marine terrace called the

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[1] G.L. Chan, Population Studies of Marine Animals in Bolinas Lagoon, College of Marin Press, Kentfield, 1967.

Bolinas Headland. Jutting out from this headland is Duxbury Reef, the subject of this report.

4. Moving north along the coast, one sees the overall beauty of the Pt. Reyes National Seashore Park. Double Point can be seen as a two-point promontory just before the concave curvature of the coastline delineating Drake's Bay and sweeping to the granitic rocks of Pt. Reyes.
5. Dotted throughout this beautiful peninsula are patches of forest-covered hills and magnificent lakes.

There can be no doubt that the land west of the mighty San Andreas fault is one of unique scenic beauty. The foresight of many men led to the creation of the Pt. Reyes National Seashore Park, a commendable action. Similarly, the scene of conservation vs. man's encroachment is shaping in the Bolinas Lagoon- a scene in which decisions will dictate either preservation or harbor development. The battle lines must be extended to include Duxbury Reef; man has already depleted many marine organisms from this intertidal area. An establishment of a marine reserve would benefit the countless numbers of future individuals who may come and use the reef as an educational experience. Of course, there will be opponents of the "marine reserve" plan. They will claim that the proposal is aimed at taking away their recreational-clamming privileges which they and their children have enjoyed for so many years. Hopefully, this report will enlighten and provide these individuals with the realization that if there are no restrictions, man will deplete this area into a "biological desert".

This report describes the current conditions of Duxbury Reef and prescribes some recommendations to preserve the marine organisms which remain.

"In the artificial world of his cities and towns, he often forgets the true nature of his planet and its long history in which man has occupied a mere moment of time." - Rachel Carson

II. DESCRIPTION OF DUXBURY REEF

Location: Duxbury Reef is located in Marin County on the Bolinas Headland, about twelve nautical miles or about twenty-five road miles northwest of San Francisco.

Name: The reef was named after the ship, Duxbury, which had crashed on these rocks on August 21, 1849. In the long maritime history of ships moving in and out of San Francisco Bay, many other vessels have met their doom on these rocks.

A. Geology of Duxbury Reef

The Bolinas Headland is composed of a thick layer of shale, called the Monterey formation, deposited during long periods of the Miocene Seas, some 28 million years ago. The basement rock below this Monterey shale is granite diorite which is exposed at Pt. Reyes and at Tomales Pt. Some excellent sea mammal fossils are found in the Bolinas cliffs to illustrate these ancient seas. In the late Pleistocene, during the past million-year interval, great block faulting took place along the whole California coast.[2] It was probably during this time when this Monterey shale Bolinas Headland was uplifted very sharply from the seas to form a marine terrace. From this late Pleistocene Period down to present times, erosion by wind, rain, and waves has cut the Bolinas Headland back, exposing the present Duxbury Reef and its vertical strata bedding planes (See Fig. 1). Much of the eroded materials was carried across the mouth of Bolinas Lagoon, forming the Stinson Beach Spit. The headland above the Duxbury Reef is still eroding back; some experts have estimated its average erosion to be about two feet per year. In a particular section, just above the base of Area C at Duxbury Reef, G. L. Chan placed a marker at the end of the old Overlook Road in December, 1958. Since that time to December, 1968, the cliff has eroded back some 50 feet from that long-gone marker (Fig. 3). Other areas of more resistant shale have shown very little erosion. Although these estimates are rough approximations, they do illustrate the continuing and powerful forces of wind, rain, and ocean waves on this promontory headland.

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[2] Olaf P. Jenkins, Ed., Geologic Guidebook of the San Francisco Bay Counties, State of California, Division of Mines, Bulletin 154, December 1951, pp. 95-106.

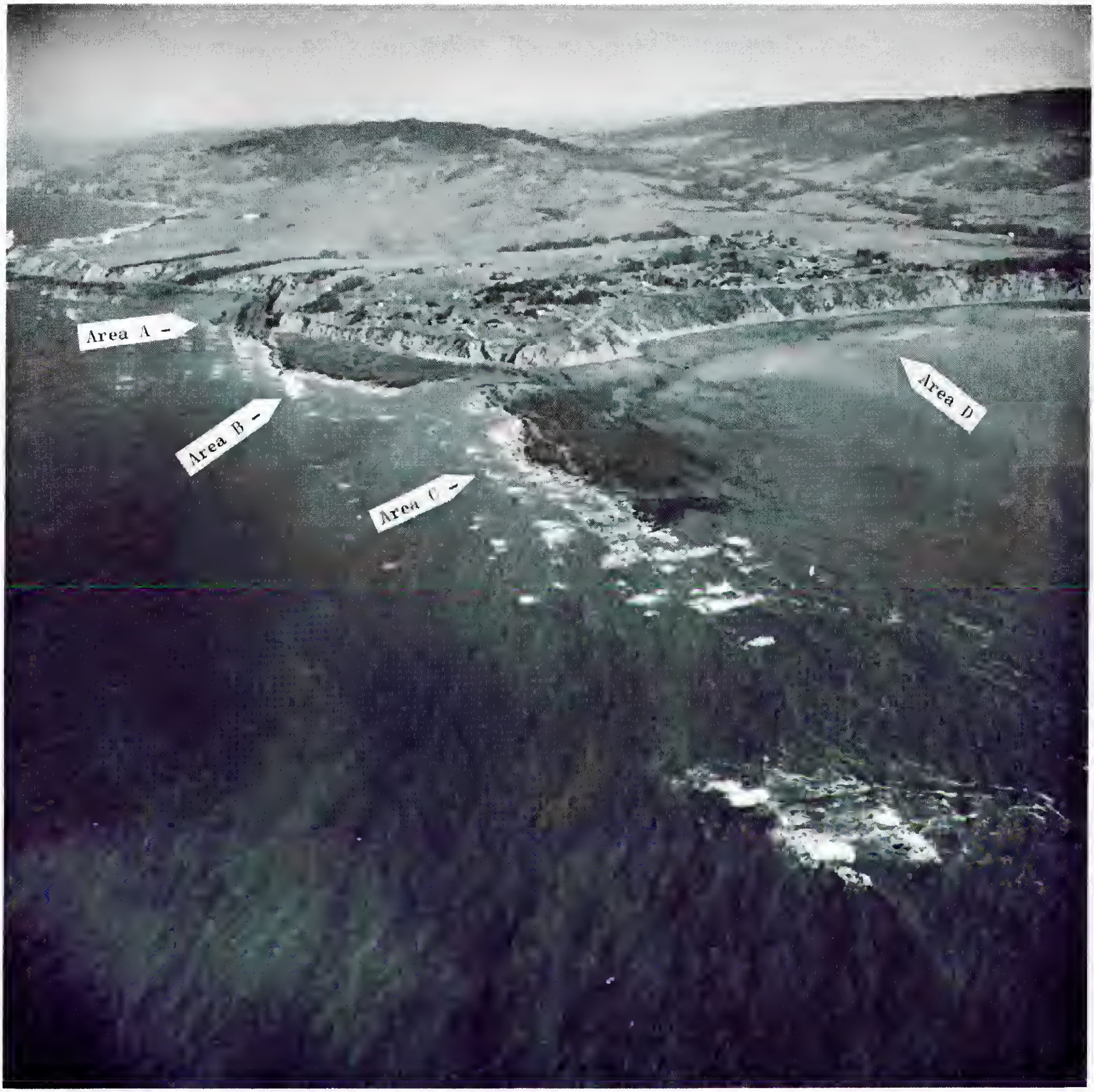


Figure 1. Duxbury Reef on the Bolinas Headland:
Eroded vertical bedding Area C of Duxbury's main reef.

The Duxbury Reef Study Areas of the College of Marin's research team is illustrated as follows:

Area A– Agate Beach Reef
Area B– Duxbury Base Reef
Area C– Duxbury Main Reef
Area D– Duxbury Sand Flats

} = the proposed "Marine Reserve"

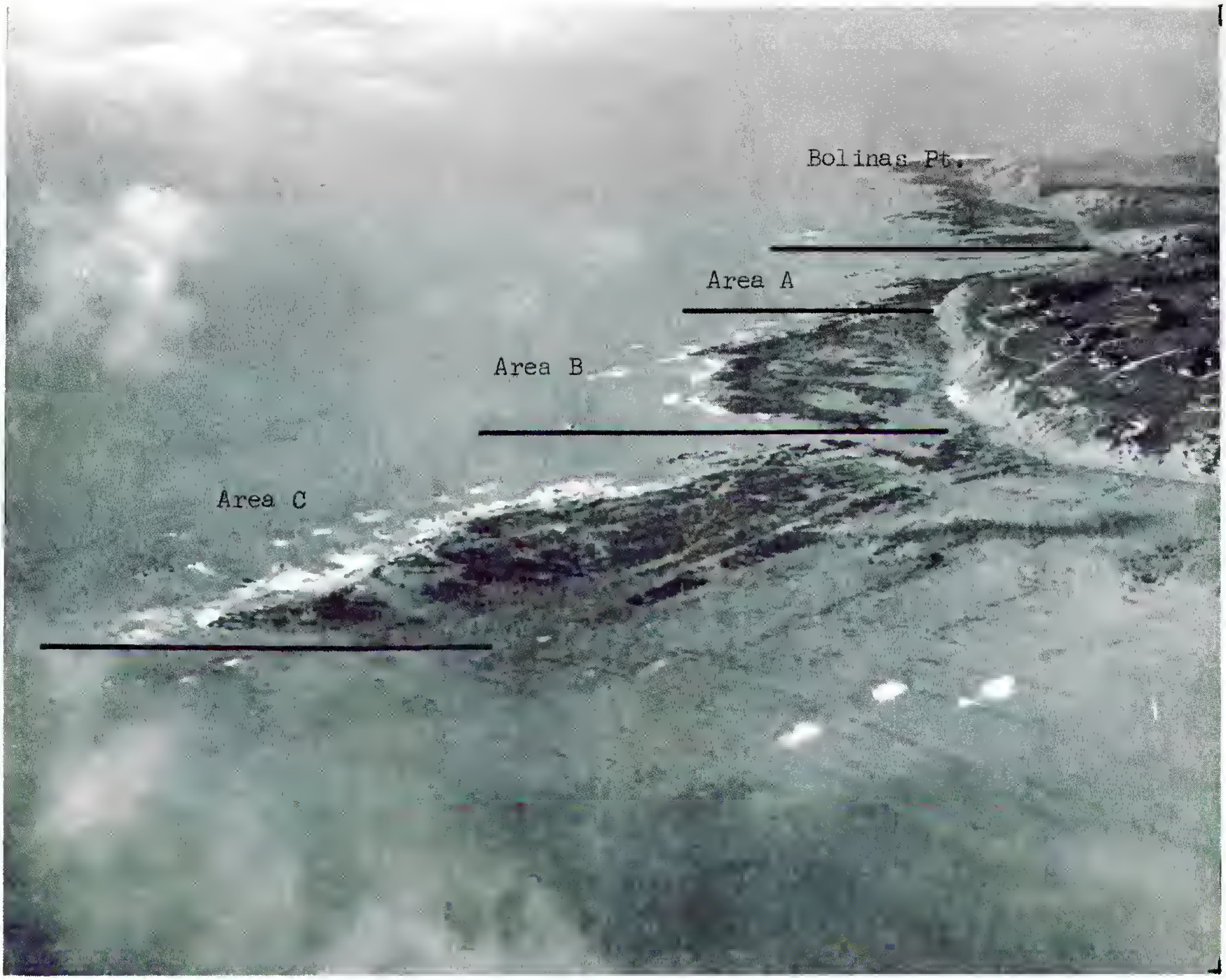


Figure 2. Duxbury Reef - Main Reef with its many flood channels and tidepools (-1.0 ebbing tide)

B. Physical Description of the Reef

The total reef area is made of shale, a stratified sedimentary rock. The wave action of the Pacific Ocean, as illustrated by the white arrows on Figure 1, has carved many tidepools and channels throughout the study areas A,B, and C (Fig. 3A). The more resistant shale ridges have remained as high protrusions, and at high tides, these high places resemble rock islands close to shore.

The physical measurement of the reef study areas (A,B,C) was the work of researcher S. McKinley and J. Phillips. These two husky individuals braved flood channels, crevices, tidepools, crashing waves, and slippery marine algae to obtain the measurements. Some basic considerations must first be assumed in these measurements. They are:

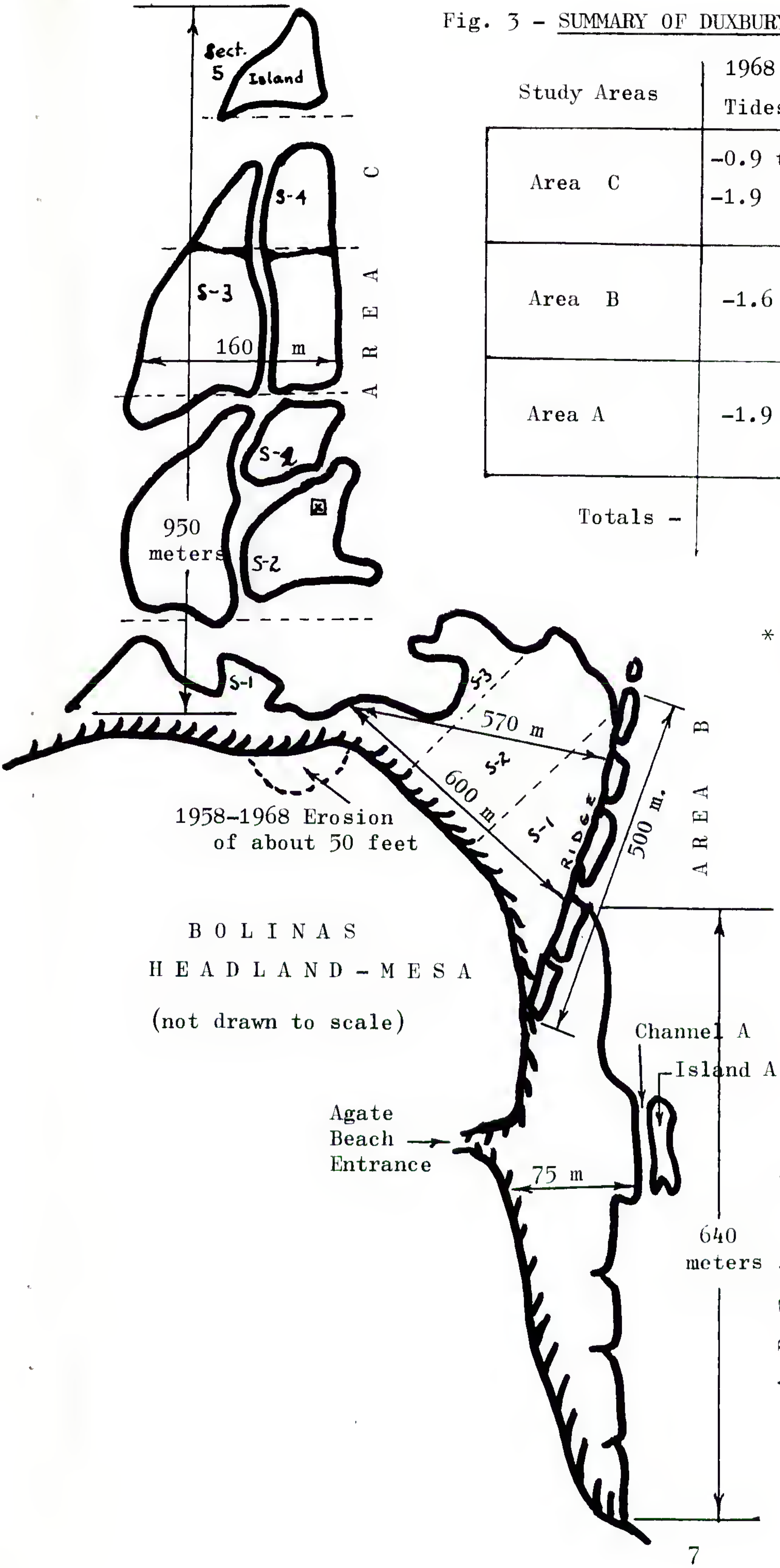
1. Area measurements fluctuated greatly depending on the degree of minus tides. The low tide of -0.7 on June 24, 1968, and that of -1.9 on July 10, 1968, revealed a substantial difference in the total exposed area of the reef. Measurements are given for minus low tidal days.
2. A 50-meter tape was used for the measurements. A downward sag of the tape may have resulted in an error of about 3 meters per 100 meters measured.
3. The measured data were subjected to the arbitrary discretion of the researchers and represent their attempt to present an accurate measurement of the Duxbury Reef study areas. The researchers welcome additional investigators who may use more advanced measuring technology and thus provide a comparison of figures to their pioneer task of reef measurement.
4. Each reef area was divided into smaller sections for measurement. Individuals interested in the details of their fine work should visit the Bolinas Marine Station for the specific data. Figure 3 illustrates some general measurements and should be considered somewhat representative of the overall reef areas.

A summary of the data is shown on the next page. There are approximately 66 acres in Areas A, B, and C. In these combined areas one could fit 61 football fields! Area C is the largest of the three study plots, this being the main Duxbury Reef which juts out from the headland approximately 1,000 meters! (See Figures 3A.) G. L. Chan has traveled to all the major reefs on the western coast of the United States, and Duxbury must rank as the largest reef as estimated by the eye. In his opinion, Sooes Reef in Cape Flattery, Washington. and Frenchman's Reef in San Mateo County rank second and third, respectively.

Fig. 3 - SUMMARY OF DUXBURY REEF STUDY AREA MEASUREMENTS

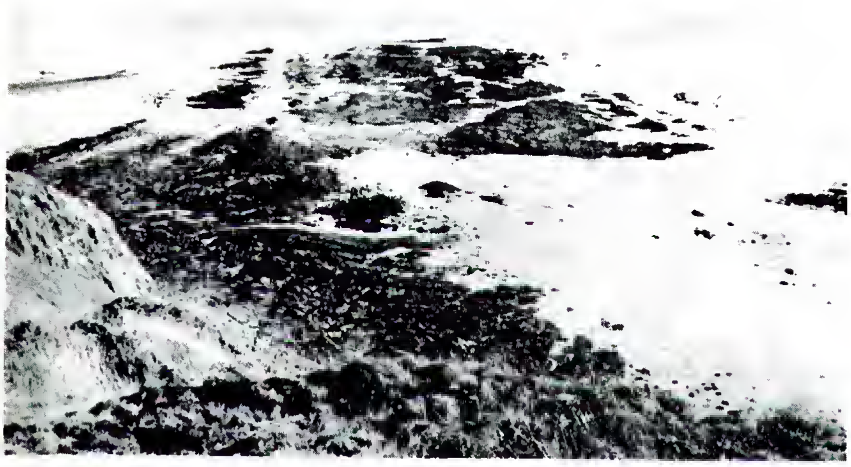
Study Areas	1968 Tides	meter^2	yard^2	acres	No. of football fields
Area C	-0.9 to -1.9	1.3×10^5	1.5×10^5	30.04	28
Area B	-1.6	8.24×10^4	1.1×10^5	22.07	21
Area A	-1.9	5.6×10^4	6.6×10^4	13.16	12
Totals -		2.68×10^5	3.26×10^5	66.07	61 *

* 61 Football Fields could fit into Areas A,B, and C



For an accurate description of each Area and its Sections, please consult the individual research papers of 1968 at the Bolinas Marine Station.

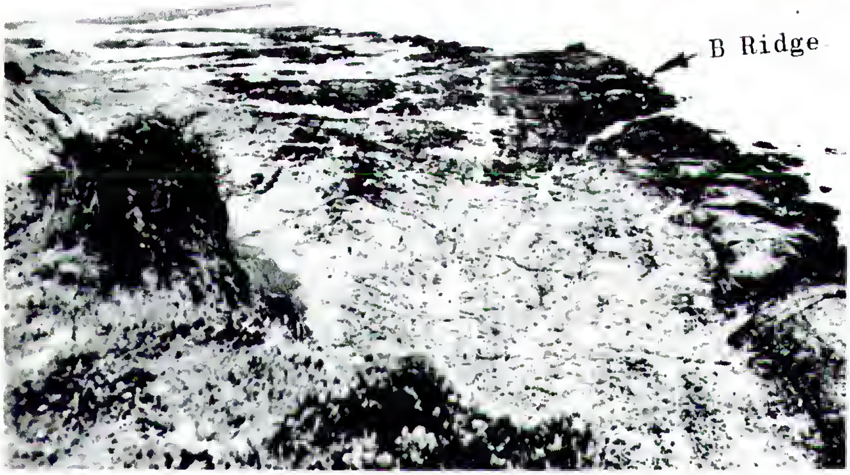
Figure 3A. Duxbury Reef Areas, Low Tide = -1.9, July 20, 1968



AREA C

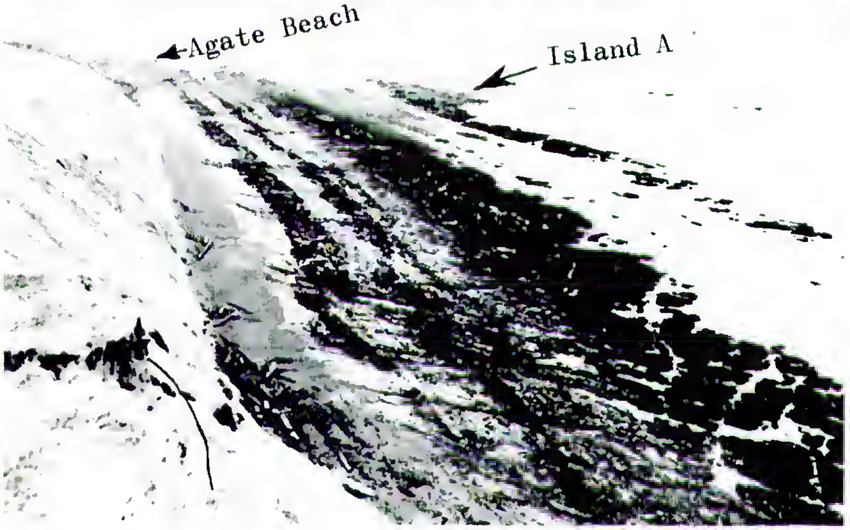
Main Reef- about 950 meters long. Sportsmen- fishermen, mussel hunters, rock clammers- venture onto this long reef.

Notice the major flood channels which can be very dangerous to reef visitors.



AREA B

Popular spot for school groups and rock clammers.



AREA A

Agate Beach- Heavily populated with all community groups, very few sportsmen.

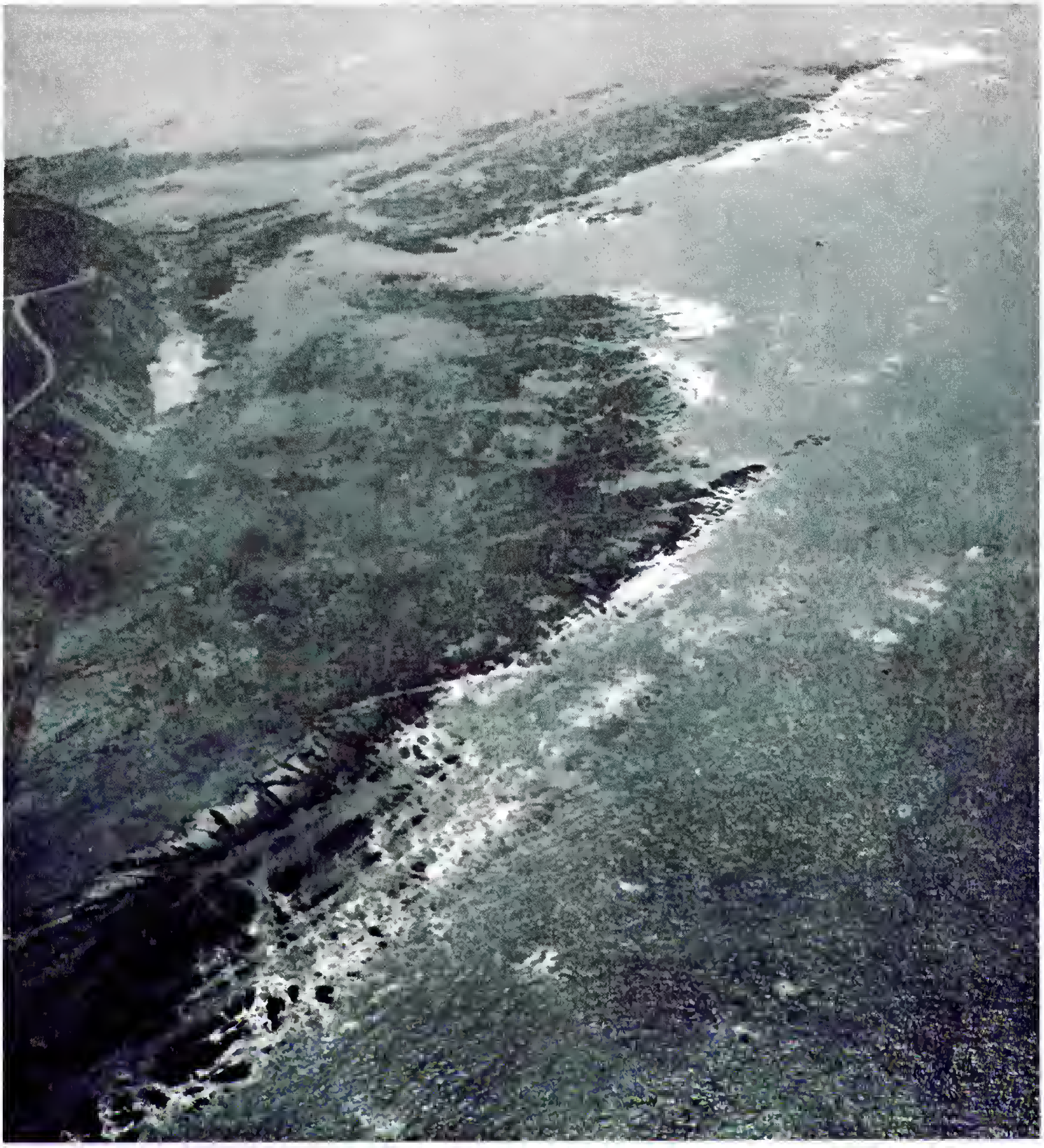


Figure 4. Duxbury Reef - Southern view, showing Areas B and C; tide is -1.0. Notice the many tidepools, crevices, and flood channels. The hard shale ridge in Area B is evident, aligned from the lower left to the upper right.

III. VISITATION OF MAN TO THE REEF

"Tidepools...promote a competitive life that is astonishing"

– John Steinbeck

With the increasing population growth in California, there is a greater emphasis on outdoor recreation. A field experience to the seashores is one of the most rewarding educational experiences. Rightfully then, more and more people have gone to the seashore for recreational and educational purposes.

Duxbury Reef has been one of the most popular seashore spots in Northern California. On low tide days, the Agate Beach access, maintained by the County of Marin, is usually jammed with people (Fig. 5).

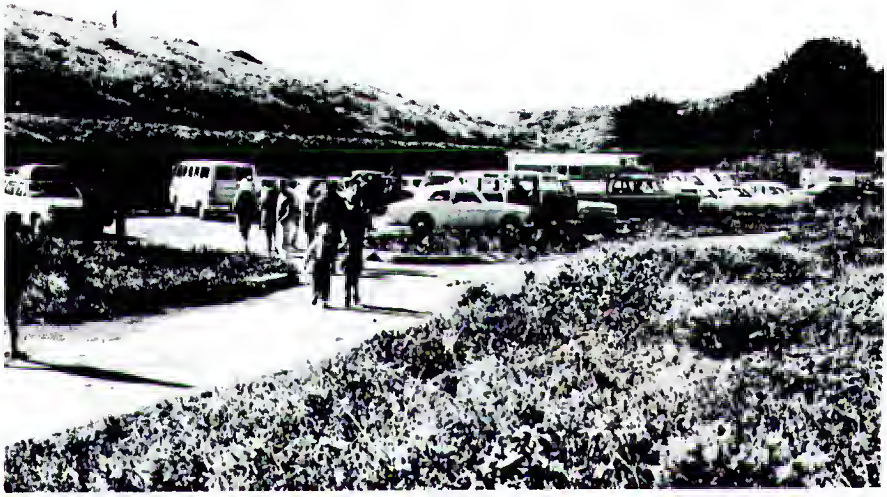


Figure 5. Agate Beach Public Fishing Access Parking Lot.

Low tide day in the spring finds a great number of people at the reef.

1. Educational Visitors

Hundreds of school children now come to Duxbury Reef each year for a field trip experience. The reef is easily accessible by a short walk from the public parking lot. Students and their teachers come from San Jose to the south, Ukiah to the north, and Sacramento to the east. These points of origin of these groups of children have been identified by the names of the schools displayed on their brightly painted yellow buses!

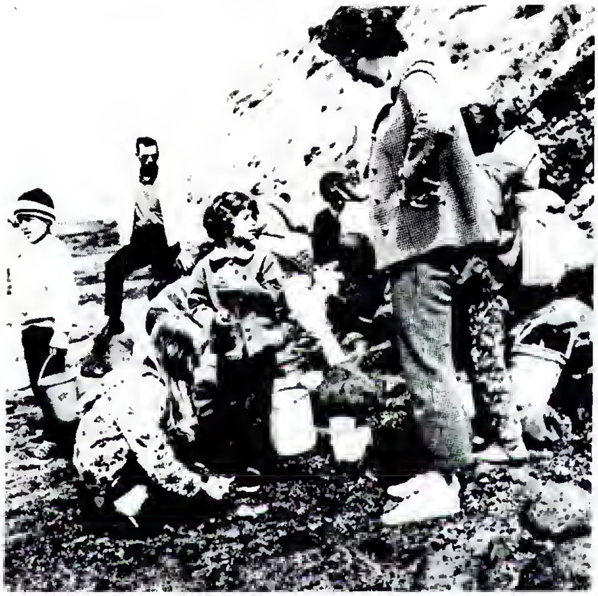


Figure 6. School children at Agate Beach with their collecting pails.

By and large, these school children are carrying buckets and other containers (Fig. 6) and have collected many large size marine animals to bring back to their classrooms and homes.

A similar scene of invasion by school children have turned the Moss Beach Reef in San Mateo County into an intertidal "desert". Thus, most of the large sea animals have disappeared from the reef, these being the sea stars, crabs, and mussels. The County of San Mateo has now decreed its Moss Beach Reef to be a "marine reserve". Students can visit the area, but cannot take out the marine life. With such a restrictive condition, students and teachers now come to Duxbury Reef to do their collecting- are we too late to preserve the remaining large marine animals on this reef?

In a ten-year comparison of human visitors to the reef during low tides, it is seen that the present visitation is grandiose. The number counts were made by G. Chan.

Observations of the number of humans at Duxbury Reef

1958		1968	
Jan 14	2 individuals total	Jan 26	38 individuals total- with about 98% confining themselves to Areas A and B. Most "educational classes" do not walk out into Area C.
Feb 13	4	Feb 24	62
April 9	3	May 17	165
July 7	5	May 18	85

It may be true that conditions in 1958 and 1968 may have been so different that a population comparison might not be realistic. The 1958 data represent the numbers of students with G. L. Chan on field trips- in those days it was extremely rare to see another person on the reefs! Nevertheless, these are the individuals observed between the two years and the intention is simply to illustrate the increased number of visitors to this reef area on low tide dates.

2. Recreational visitors

Another group which uses the reef are the sportsmen with various interests.

a. Some are clammers.

b. Others use the reef for surf and tidepool fishing.

c. Some fish for mussels and abalones.

d. A small number are duck hunters.

Let's examine these groups one at a time.

a. Clammers

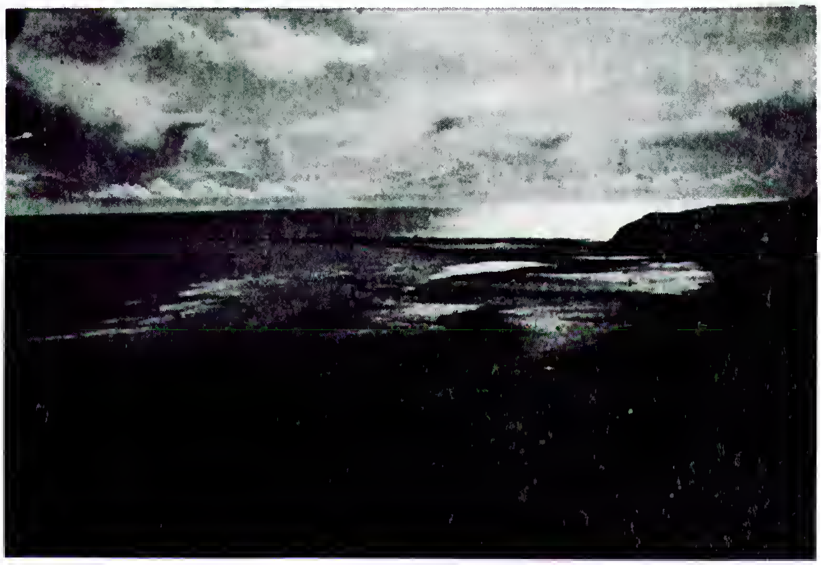


Figure 7. View of Duxbury Sand Flats, labeled as Area D (see also Fig. 1). Duxbury's Main Reef, Area C, is in the distance.

On days of low tide, there are numerous clammers on the Duxbury sand flats, Area D, Fig. 7, scraping the upper sand surface for the butter clam, Protothaca staminea. The Fish and Game limit on this clam is 50 per person. This clam is also widespread in Tomales Bay with small patches also remaining in the Bolinas Lagoon. Year after year, the authors climbed over these flats and interviewed the clam diggers. In our opinion, there does not seem to be any appreciable decrease in the clam population of Protothaca staminea to warrant any serious limiting of digging in this area. Fish and Game rules seem to adequately protect this organism in this area.

A second group of clammers poses some threat to the structure of the reef. These are the sportsmen who carry picks, chisels and hammers to the rocky shale portions of the reef areas A, B, and C. These rock clammers chop through the soft shale rocks to pick on the boring clams which have embedded themselves from 3"to 10" deep for protection (Fig. 8 and Fig. 9).

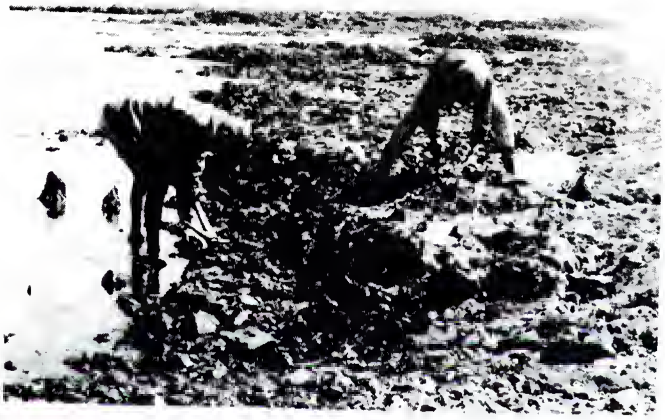


Figure 8. Clam diggers chopping through the shale for rock boring clams.

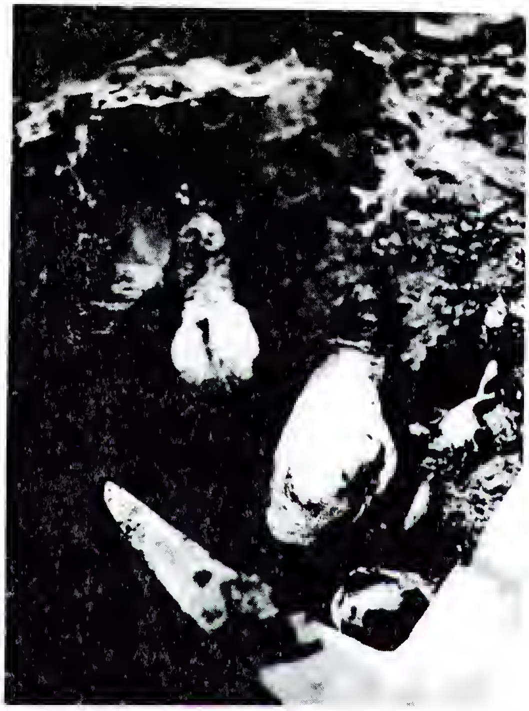


Figure 9. Rock boring clam, Platyodon cancellatus.

Further on in this report on the discussion of the population of rock boring clams, we find there is no decrease of this clam. In fact, this clam is one of the most abundant organisms on the reef. The damage these clammers perform is in leveling the reef! Frenchmen's Reef in San Mateo County is one where clammers have chopped the reef until it nearly resembles a smooth billiard table. Duxbury Reef still has many intricate rock and crevice heights, but if these diggers continue over the years, the reef will be flattened except for the hard shale mounds where no clams are to be found.

The erosion effect of rock clammers may be greater at times than the watery forces on the reef. At Area B of the reef, near the outer ridge, G. L. Chan and students observed two men "clean" a 10-square yard area of shale, decreasing the height by an average of two feet with their picks! Since there is no "limit" on the take of these clams, one chops away until exhausted or the tide comes in. The leveling effects by these diggers might cause the low tides to keep submerged many areas which previously had been exposed. Moreover, this leveling destroys the habitats (crevices) for many marine animals. The rock clammers are not numerous at the present time- low tides bring out an average of about four; however, there will, no doubt, be increasing numbers of diggers in years to come. Although the rock clams are very abundant, the question arises as to whether the reef itself is worth saving. The authors recommend rock clamming be prohibited under the "marine reserve" park regulations.

b. Fishermen

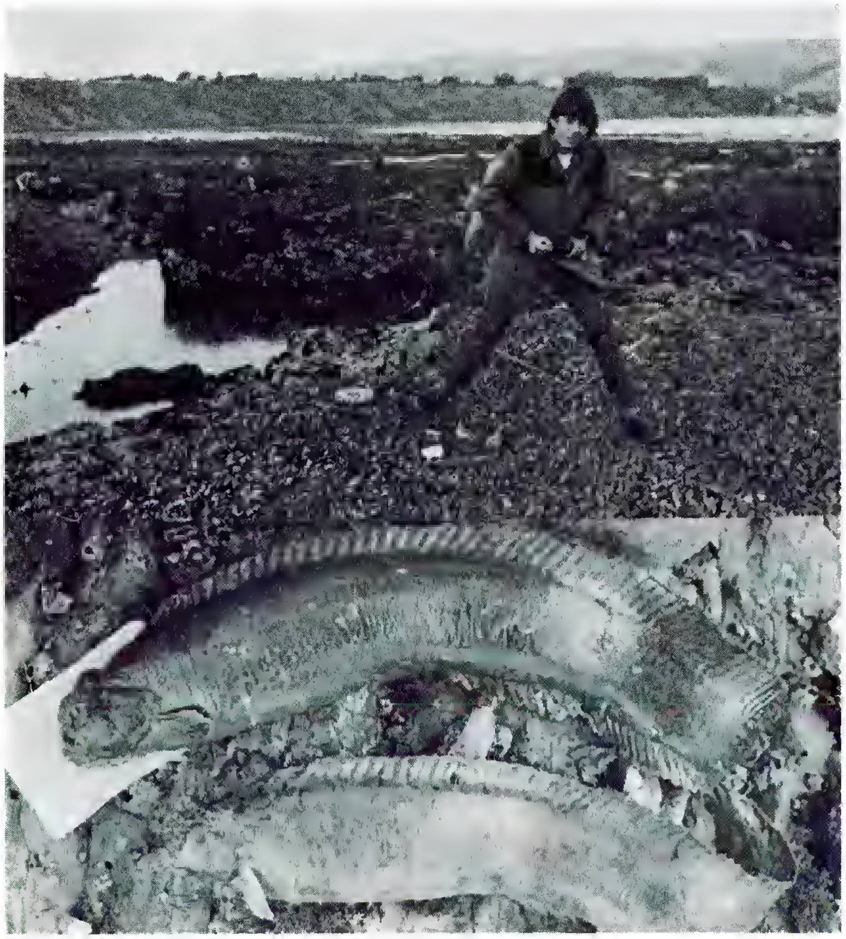


Figure 10. Duxbury Fisherman. These fishermen are after the Monkeyface blenny, Cebidichthys violaceus. Mussel flesh is used for bait.

The average number of fishermen per low tide is about 6. Figure 10 shows individuals fishing for the numerous blenny eels which may reach lengths up to 25 inches on the reef.

Other fishermen fish for the abundant surf perches, sea trouts, and cabezons. These individuals usually use the California black mussel for bait. (Fig. 10.) The reef should provide an access for this type of sport activity in the event the "marine reserve" is established with no restrictions as to the use of mussels for bait.

c. Mollusk Fishermen - mussels and abalones

(1) Mussel fishermen

Later in this report, there is an extensive discussion on the poplation of the mussel, Mytilus californianus. But for now, the discussion is limited to the fishermen who take this for food during winter low tides. (In the summer months, this organism is quarantined.)

There is no limit on the number of mussels one can carry off the reef. During winter low tides, there is an average of about three mussel fishermen. They use a pick and scrap off yards of these mussels, or as many as they can comfortably carry off the reef in their gunny sacks.

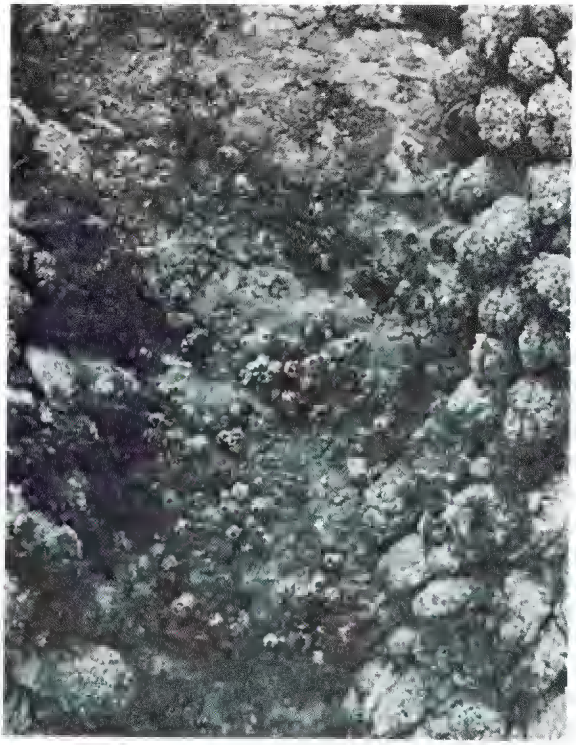


Figure 11. A cleaned out section of the mussel bed, Mytilus californianus. Notice some "succession" or repopulation after one year (1965-1966).

In Figure 11, G. Chan has observed this cleaned-out spot for three years, and the mussel replenishing has not occurred. More about this study further on in this report. If the "marine reserve" is in effect for this reef, there should be a limit take of 50 mussels per person, with a minimum mussel length measurement of four inches. In Areas A and B, the large mussels have all been picked off; in fact, the largest mussels observed in Area A the summer of 1968 were about 2½ inches long!

(2) Abalone fishermen

The photos below (Figure 12) are rare pictures indeed. The student is holding a 9-inch red abalone, Haliotis rufescens, from the outer sections of Area C of Dxubury Reef, July, 1968. Such large specimens are extremely rare, and even finding abalones on the intertidal reef is a very uncommon occurrence.

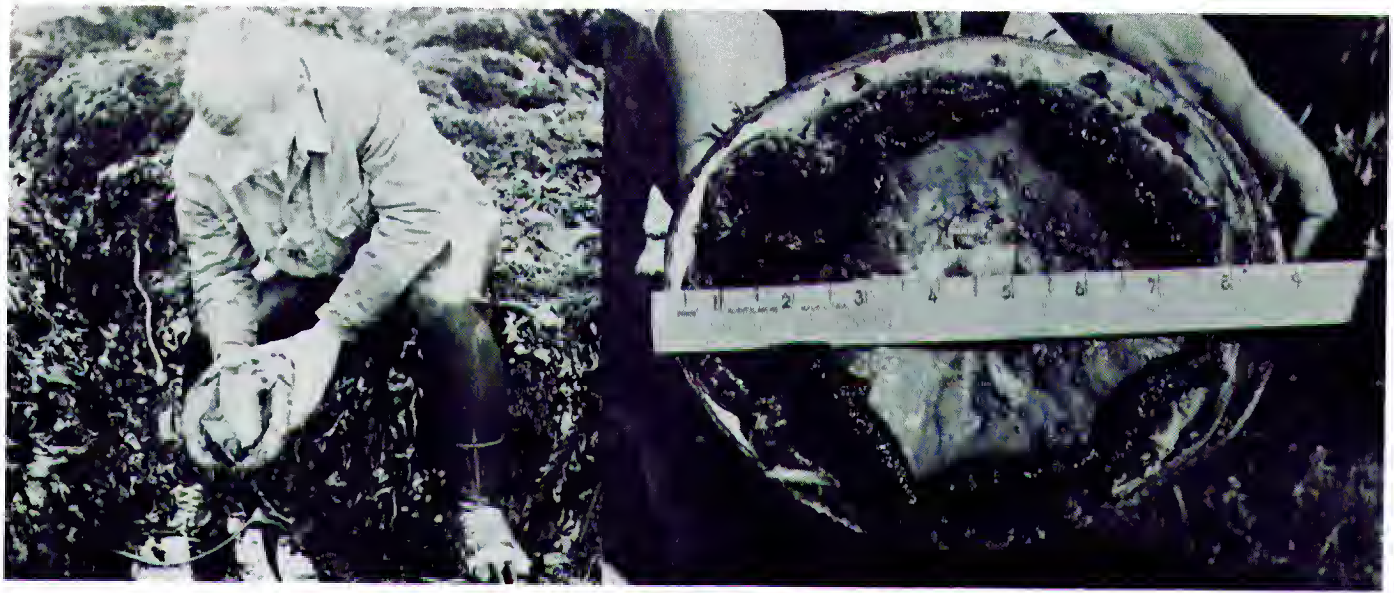


Figure 12. Scott McKinley holding a 9-inch abalone, Haliotis rufescens, taken from Duxbury Reef.

In the 1940's and 1950's G. L. Chan used to see abalones on trips on the reef. However, abalone fishermen have long since "cleaned out" the intertidal zone. Thus on low tides, it is seldom that one sees an abalone fisherman on the reef; word of mouth has convined these individuals that it is a waste of time to look for such animals here. In the "marine reserve" there should be no abalone hunting permitted. In time, it may be that some of the deeper forms would migrate up into the intertidal waters, although abalone migration from one spot to another is not supported by scientific data. Perhaps some abalones may be brought in from deeper waters and be established in the intertidal areas for educational purposes on the reef reserve.

Figure 13. Teacher and students observe marine worms from the underside of a rock at Duxbury Reef. The rock was carefully returned to its original position after observation.

It is not the intent of this report to keep people off the reef. Californians should be able to visit these reefs at all opportunities. The purpose of this report is to recommend that the Duxbury Reef areas be designated as a "marine reserve" by the County of Marin. It would then be a misdemeanor to take certain specified marine organisms away from these areas. The reef should be a spot for many groups (Figure 13) to enjoy a rich marine experience. The abundance of tidepool organisms should be preserved for all present and future generations of Californians to enjoy.

The question now is, what is the present condition of the marine organisms on the Duxbury Reef areas? Are we too late to preserve some of the large marine organisms? What other data can be specified concerning the importance of conserving organisms on Duxbury Reef? A review of Duxbury marine organisms now follows, then specific recommendations will be listed.

IV. POPULATION STUDIES OF MARINE ORGANISMS ON DUXBURY REEF

Problem: Is there a difference in the population of marine organisms between the different areas (A,B,C) of Duxbury Reef?

Hypothesis: In general, there should be less large-size marine organisms at Area A (Agate Beach) and subsequently more organisms the further out one moves towards the extremities of Area C (Duxbury- main reef). Man's collecting habits might account for the difference in population.

This overall problem and hypothesis will be the general theme for the following studies on Duxbury Reef's marine population. The reef in some areas is extremely rich in marine organisms (Figure 14) and barren in other areas, especially near the Agate Beach entrance (Area A). The large marine animals will be the focus of the studies, omitting the small marine worms, etc., which are normally overlooked by people on a collecting or sporting excursion.

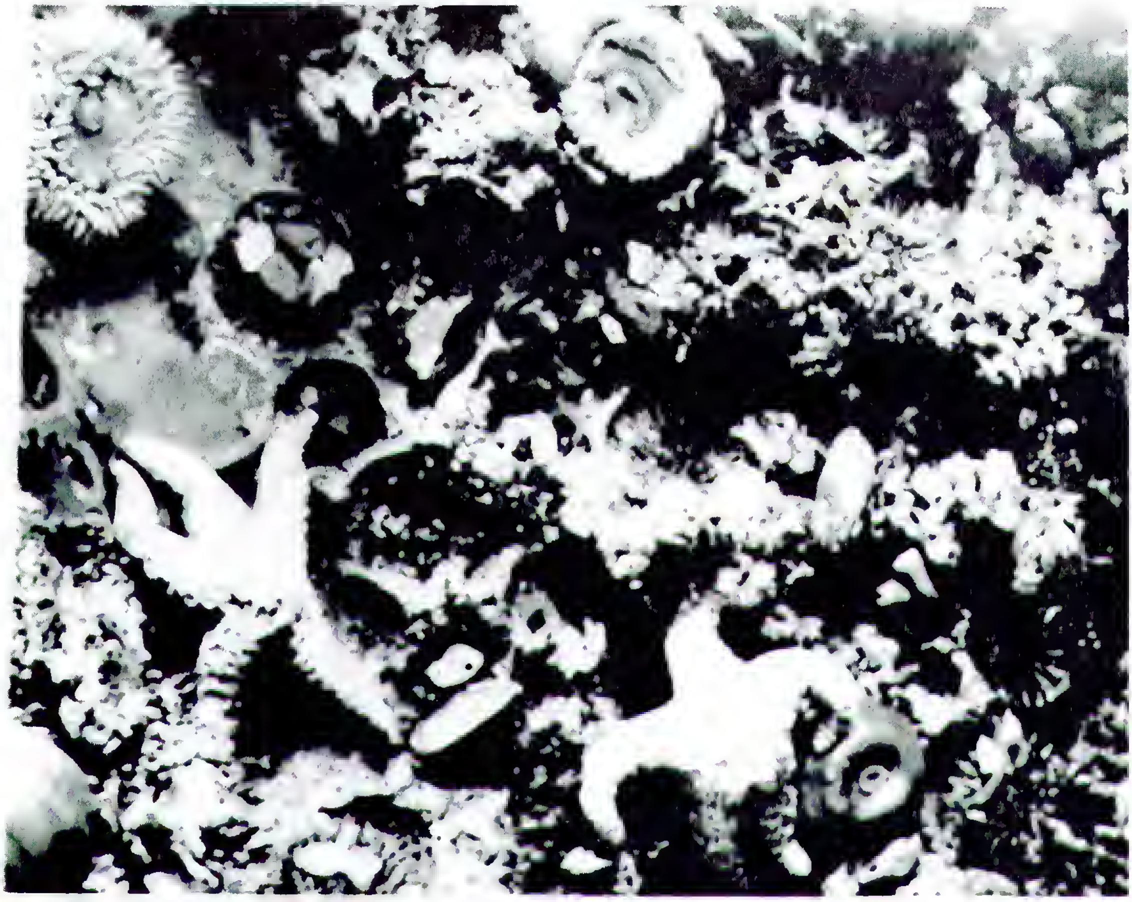


Figure 14. Tidepool Life at Duxbury. Can you identify the following marine organisms: sea stars (starfish), sea anemones, sea urchins in their holes, and the California mussels? These four are part of Duxbury Reef's major species.

The following section in this report touches on the research studies on the major large-size marine organisms commonly found on Duxbury Reef. A summary table, page 45, lists the chief numerical distribution of each major organism.

A. Sea Anemones

The study of major organisms will begin taxonomically with two dominant sea anemones found throughout the reef areas: Anthopleura xanthogrammica and Anthopleura elegantissima.

To the reef visitors, both anemones look similar, resembling flowers. To the biologist, these fringe-like projections are tentacles filled with poisonous stinging cells (nematocysts) which are characteristic of the phylum, Coelenterata. These carnivorous animals will prey on many other animals which come into contact with their tentacles, engulfing the trapped organism down into its single opening, the mouth. There seem to be no known marine predators of these coelenterates-it may be that these sea anemones are too poisonous for other creatures to digest.

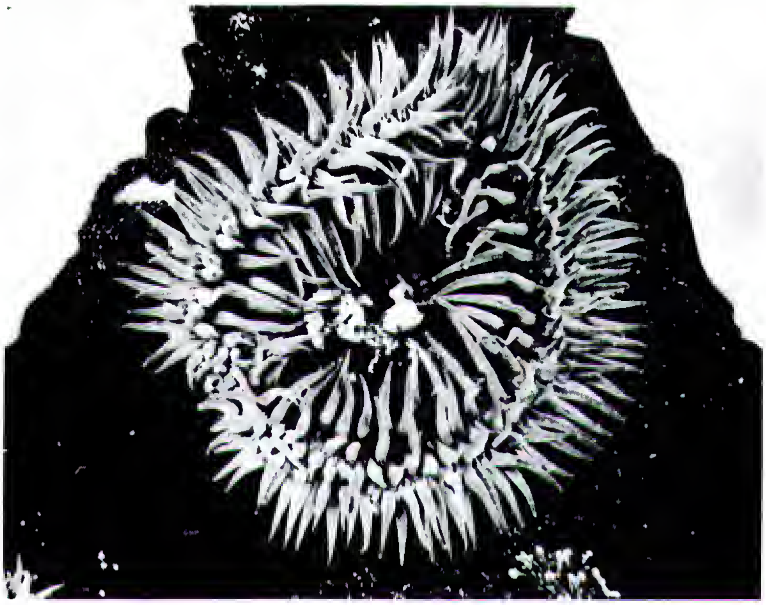


Figure 14. Anthopleura xanthogrammica, the giant green sea anemone. This particular one is known as "Anthony Chan", photographed in December of 1967.

A. xanthogrammica, Figure 14, is the larger of the two species which were studied; in fact, outside of some deep water anemones (Metridium spp.), it is the largest of intertidal sea anemones on the west coast.

G. Chan has recorded the growth of a specific A. xanthogrammica for ten years, 1958-1968. This data may be the only vital statistics ever recorded on one sea anemone over a period of time. This particular specimen is found in a tidepool in Area C, Section 2-- On page 7, Figure 3, an X marks the approximate location of this anemone. In the ten years, this anemone (fondly named by his students as "Anthony Chan"- Fig. 14) has been fed with the choicest of food, mainly mussels from the outer sections of Area C. Measuring this animal has been a difficult task, like trying to slip a tape measure over a contortionist. The following technique was used: "I rubbed the anemone with my fingers until it was fully contracted, Figure 15; at that moment, I dropped a large caliper around the anemone and measured the widest points in the contracted column." The two significant "before and after" measurements of "Tony Chan" are:

Date	Column Diameter	Column Circumference	Longest Tentacle Length
June 2, 1958	6"	18.8"	2"
Nov 19, 1968	8"	25.1"	$2\frac{1}{2}$"

In ten years, this anemone has put on two inches of muscle; student admirers have claimed "Tony" to be the "world record" or largest of its kind, especially for one which has been carefully nurtured with mussel meat for over ten years. Another sea anemone, which was next to "Tony" and was smaller at the onset of this feeding experiment on "Tony", measured 3" and $3\frac{1}{2}$" in its before and after diameters. Its growth has not been as significant. What does all this mean? Well, one could postulate that the more one(anemone) eats, the bigger one gets!

How long do sea anemones live? "Tony" has been alive well over ten years. In England, there is a report of another pet sea anemone passed down as a family heirloom in an aquarium for three generations, making it well over 60 years old!

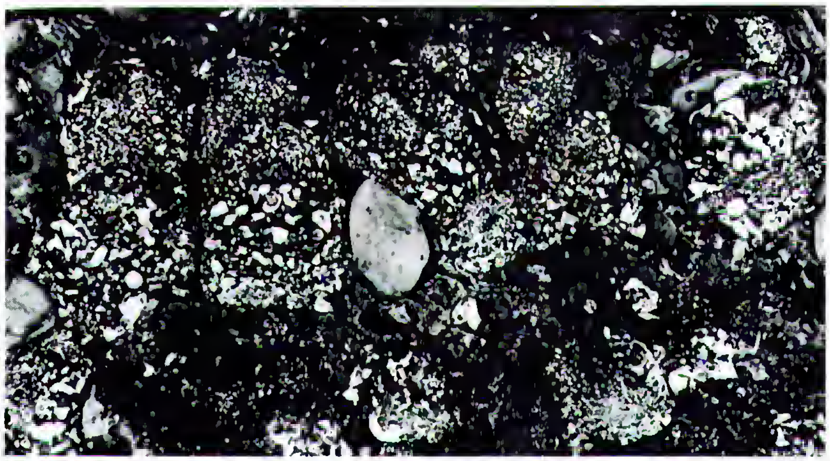


Figure 15. A. xanthogrammica, contracted anemones with shell parts on their dark green columns probably for prevention of desiccation.

The ecology of A. xanthogrammica is certainly one of many fascinating studies which man can perform on a reef. It may be that much biological inference can be learned from the study of anemones—such as longevity through particular diets! The animal also illustrates much possible adaptations by collecting broken shell parts on its heavily mucoused dark green (an algal symbiont) column to prevent desiccation during prolonged periods of sun exposure when low tide occurs.

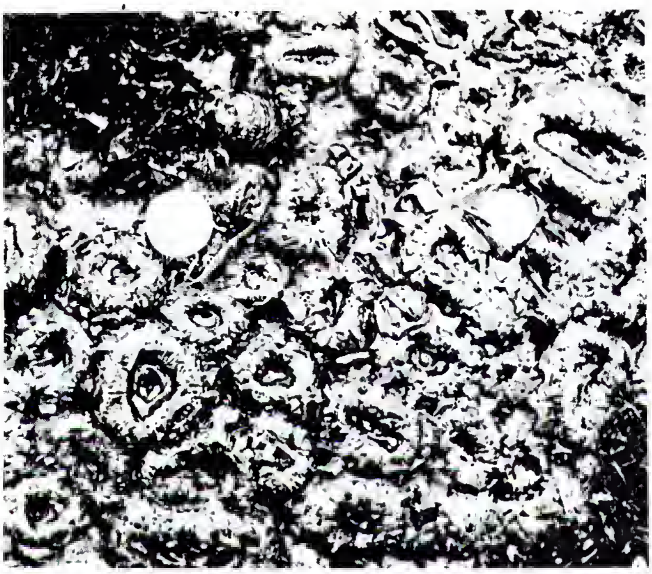


Figure 16. A. elegantissima, contracted stage of this small aggregating anemone. The coin was used for size contrast.

Anthopleura elegantissima, Figure 16, is much smaller than A. xanthogrammica. This anemone is considered to be an aggregating organism, living in thick patches to protect itself from wave actions. This anemone generally is found to be quite abundant on the protected tidal flats of the reef-away from the low tidal surf.

Since both species of sea anemones are found in crevices or in tidal pools, counting was made quite difficult and somewhat inconsistent. Investigator Robert Hamilton's technique was to walk in parallel lines over the reef. At crevice intersections he would count the anemones of both species. Obviously bias and errors are introducted in this type of sampling. The value of the numbers produced in this anemone report and in all of the subsequent marine organisms studies are reflected in an honest attempt to reveal the nature of the numbers of organisms living in each area of Duxbury Reef. Mr. Hamilton's population numbers revealed the following:

	Observed Sea Anemones		
Areas	A. xanthogrammica	A. elegantissima	Totals
Area A 21 samples	6	1,413	1,419
Area B 16 samples	305	2,900	3,205
Area C 14 samples	8,300	36,000	44,300
	8,611	40,313	48,919

In reality, Mr. Hamilton's numbers are only pertinent to his own particular counts. It does show an enormous difference in anemones in the three areas. A second person, using a slightly different transect methodology might obtain different numbers. G. Chan's counts: "I walked over other areas which Mr. Hamilton did not cover with his transects. I, too, covered the reef by using parallel transects and counting anemones in tidepools and crevices. Counting only *A. xanthogrammica*, the large green anemone, I arrived at these figures:"

Areas	Counts of *A. xanthogrammica*
Area A (Channel A, Island A)	32
Area B Section 3	168
Area C Section 4	448
Total	648

These numbers represent the count of anemones over approximately the same size areas in A,B, and C - all three cover a total area of about 50 x 50 meters. The significance of both anemone counts is that the numbers do show a smaller total in Area A than B. and Area C is the most heavily densely populated area.

Some Generalities

1. If we assume Areas A,B, and C to be somewhat ecologically similar- that is, the geography of the reef areas approximates the same conditions for the populations of marine organisms, then one has to ask why Area A has fewer anemones.
2. If we further assume that anemones have no natural predators, then the less dense numbers in Area A may be due to the collecting habits of the large number of human visitors to this reef area. Obviously, the only way we would know that this assumption is true would be to observe every low tide and record the numbers of *A. xanthogrammica* being pried off and thrown into buckets. Naturally, this task has not been done. What has been done is small; some bucket observations have taken place and sea anemones do rank as consistent bucket specimens.
3. The intent of showing numbers in this anemone report is to document some records which may illustrate what man may have done in heavily populated reef areas."Perhaps I have a deep fear that someday someone may pry "Tony" off and thus end this beautiful and long-lasting friendship!" Nevertheless, it has to be said that it is more beneficial to *all* concerns if observations were to take place in the field rather than in the classroom where the specimen is taken and will eventually die-- this is the objective of these studies. to protect what remains.

B. Chitons

Chitons are classified as mollusks, and represent remnants of ancient organisms which occupied the sea floor millions of years ago. Belonging to the class, Amphineura, chitons are commonly called Sea Cradles. In a smooth rock habitat, chitons generally dig out a cradle-like groove (Figure 18).

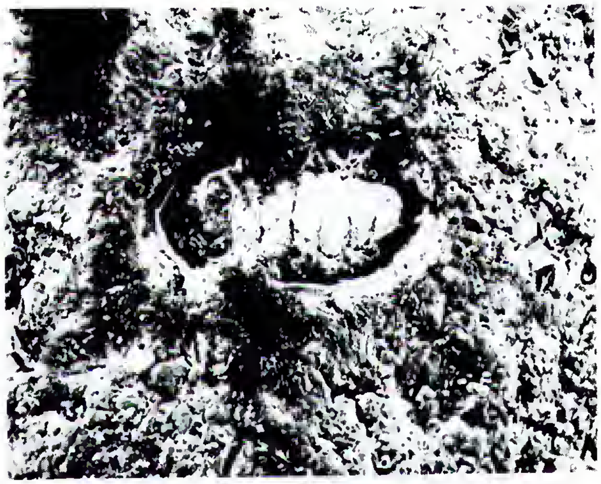


Figure 17. Chiton, Mopalia ciliata, not well camouflaged.

Chitons are identified by their characteristic eight dorsal valves or plates (Figure 17), although there are times when these plates are partially or completely covered with algal growth (Fig. 18); some species have these plates covered with their mantle.

The importance of the chitons is related to their place in the food web with marine predators. Their soft foot makes them choice prey for a variety of fish, crabs, anemones, etc. Man in general does not eat the chiton, although sport fishermen, when they can find these animals, will pry them off and use the foot for bait. Marine biologists find the chiton choice animals to study because its bilateral symmetry places them near the primitive head of the molluscan taxonomic structure. Ecologically, its role and movement in the marine habitat make it a prize animal to observe. The gumboot chiton. Cryptochiton stelleri, whose reddish mantle covers its dorsal plates, is the largest chiton in the world, up to 18 inches in length, and can be seen in Area B, section 3. Again, we hope this publicity does not cause an immediate decrease in these primitive molluscans!

The researcher, T. Gabrielson, limited his population studies to two species of chitons, Mopalia ciliata (Fig. 17) and Mopalia mucosa (Fig. 18). Both these chitons are found on the surfaces of the intertidal shale flats and can be counted if the investigator knows the differences between a camouflage of chiton and the surrounding marine algae (Fig. 18). Other species are found in crevices and under rocks. Flipping the chiton over, one sees its protective cradle home and the tiny grooves made by the animal's rasping tongue, the radula. Chitons are generally nocturnal algal feeders.

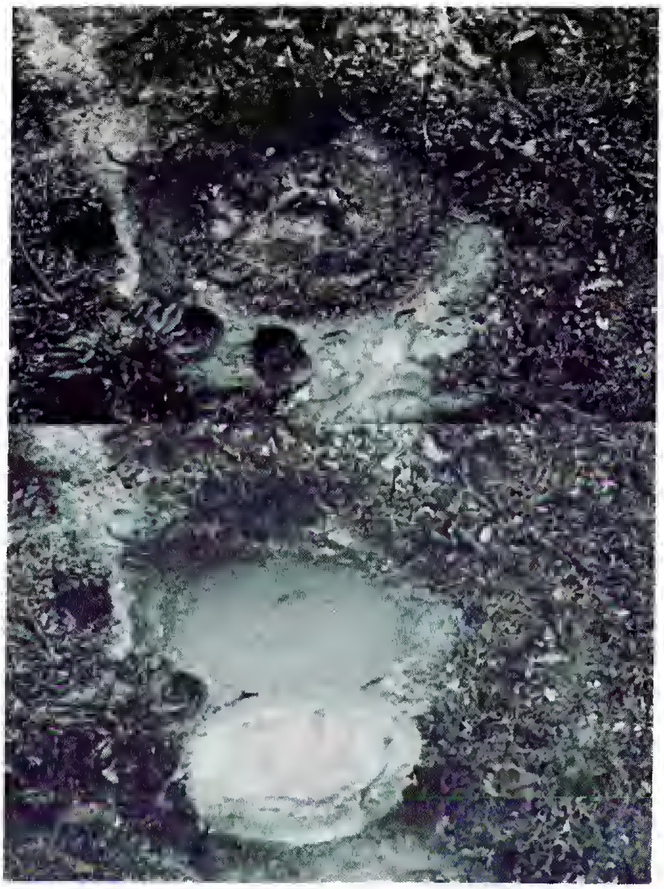


Figure 18. Mopalia mucosa. Top photo: The chiton is well concealed with the algal growth. Bottom photo: The chiton's vertical foot and mouth are exposed.

Mr. Gabrielson's sampling technique involved parallel transects, and recording every 12-meter interval along each transect. At each interval he sampled an area of 36 square meters; 48 such intervals were recorded in Areas A,B, and C. He also limited himself to counting chitons between the size of 1.25 to 7 centimeters (about one-half inch to nearly three inches), the latter being the largest he observed. In other words, he probably could not find nor see chitons smaller than 1.25 cm.

Many empty chiton grooves were observed by Mr. Gabrielson. He speculated that some of these grooves were made by chitons hundreds or even thousands of years ago. No methodology was available to determine such ages. Other empty grooves show recent occupancy. Those grooves which had radula markings were "new" as compared to the old ones which were smooth. In some areas, there were about three empty chiton grooves to every chiton counted.

Summary of collected chiton data on *M. ciliata* and *M. mucosa*:

		No. of Chitons	Ratio of empty chiton holes to chitons
Area A:	Beach flats = 3		
	Rocky flats = 13	16	2 holes to 1 chiton
Area B:	Section 1 = 47		
	Section 2 = 13		
	Section 3 = 6	66	1 hole to 1 chiton
Area C:	Section 1 = 12		
	Section 2 = 28		
	Section 3 = 27		
	Section 4 = 12	79	3 holes to 1 chiton

Total observed = 161
from 48 sample intersections

General Assumptions

1. The fewest chitons were counted in Area A, the Agate Beach area. The lower number of chitons in Area A may be attributed towards a combination of a decrease in algal food material and possibility of being picked up by school children on field trips. The highest section, Area B, Section 1, contained 47 chitons and this area is not as heavily peopled as Section 2. It is our opinion that those amateur collectors walking over Section 1 do not see many of the algal-camouflaged chitons.
2. Area C has the most empty chiton holes. Since this area has also the most sports fishermen, we assume that these seasoned veterans can spot the chitons and use these for bait - thus, the assumption for the higher ratio of holes to chitons.
3. The recommendation is that all chitons be a protected species from the collectors as well as the fishermen. Fishermen should use the mussel for bait (see the following section on mussels).

C. Mussels

The California mussel, Mytilus californianus, a bivalve belonging to the phylum Mollusca and the class Lamellibranchia, is probably the most dominant marine organism on Duxbury Reef. These bivalve animals exist in large strips and patches along the wave swept rocks of the intertidal region. The mussel can withstand great wave shock by securing itself with its byssal threads and aggregating itself in dense numbers (Fig. 19).

The ecology of mussels form a very fascinating body of knowledge for marine biologists. The bibliography encloses some of the works by outstanding individuals - in particular, the standard bible of Pacific Coast marine life, Ricketts and Calvin's text, "Between Pacific Tides". Researcher Gary Williams of our team has also contributed heavily with his fine paper on: "Investigations into the Ecology and Population of Mytilus californianus at Duxbury Reef". This paper, like the others, may be read at the College of Marin's Bolinas Marine Station (Appendix 4). Enclosed in this report, Appendix 1 is the list of the marine organisms which inhabit the same niche as the California mussel. The protective "housing" provided by the aggregating mussels would ideally provide a "built-in city" for many residents. The classic study of mussel beds is that done by Hewatt in 1931.[3] He scraped off a square yard (Fig. 19) of mussel bed down to the bare rock. In this area, he counted 1,612 mussels, and with other animals living in and underneath this mass, he counted a total of 5,165 marine animals! (Also see Williams' list, Appendix 1). Considering our previous reporting on the regeneration of a scraped off mussel bed, let's now discuss what has been studied at Duxbury Reef.

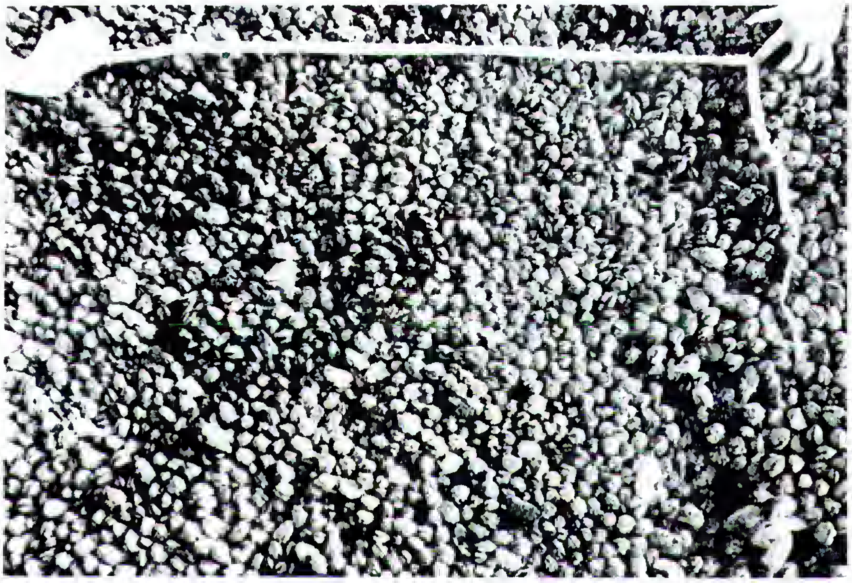


Figure 19. A square meter of mussel bed, Mytilus californianus. There are over 5,000 marine organisms living in this square meter!

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[3] E.Ricketts, J.Calvin, J.Hedgpeth, Between Pacific Tides, Rev. 4th Ed. by J.W. Hedgpeth, Stanford University Press, 1968, p. 398.

Suppose a mussel fisherman scrapes off a large patch of mussels, what is the repopulation or succession rate of marine animals which occupy this space? This question is stated as such because many such empty patches have occurred and have been observed at Dxubury Reef by fishermen and a few by this author.

Hewatt's study indicated that after one year's time, from a clear patch of granite rock, 89 mussels repopulated this space. He did not follow through as to how long it took to have the total patch reoccupied to its previous conditions.

In 1957, G. Chan cleaned off a square meter patch at Area C, section 4, of Duxbury Reef. This patch was completely repopulated by mussels in 1967, a total of 10 years for complete succession to take place. This square meter was cleaned out of a center of a larger patch of mussel bed. What would happen if a strip were cleaned out, starting from the edge of a mussel bed? On December 7, 1965, we again cleaned out a strip, 15 feet long, one foot wide, in Area C, Section 4, of Duxbury Reef. The natural succession of algae, barnacles, limpets, etc. has filled in some of the bare surfaces. After nearly three years, on July 10, 1968, the strip was 12 feet long, shortened by some three feet, but was still about one foot wide on the average - Figure 20. This experiment will continue as long as there are investigators at the Bolinas Marine Station. However,we do not expect this strip to be filled in within 10 years as occurred with the square meter patch which was removed from a larger section of mussels. The reason this strip will be kept open longer is that wave action and scouring prevents a consistent repopulaation and it will take many more years for the strip to close in at the top. Also, how many fishermen have kept the strip open by conveniently taking mussels from the edges of the experiment?!!

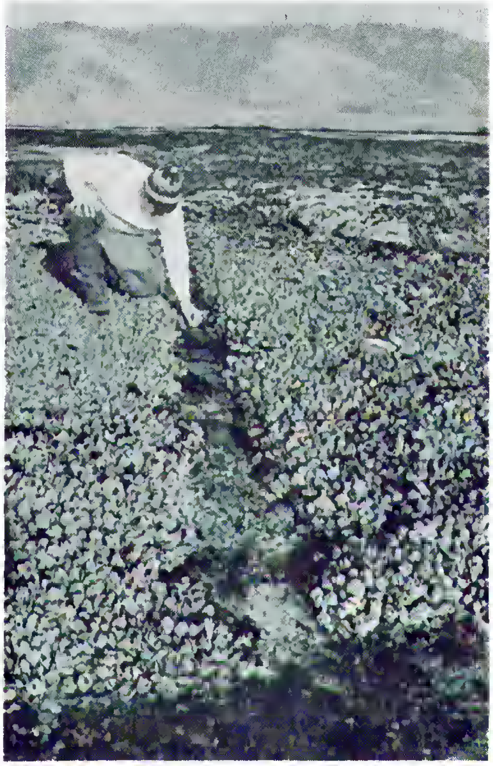

Figure 20. Mussel strip succession experiment after nearly 3 years, photo taken on July 10, 1968.

In general, a fisherman who takes mussels by cutting strips will inhibit the rate of repopulation and succession more than if he were to take mussels from within a larger patch of mussels.

Under the direction of G.L. Chan, researcher G. Williams' methodology of sampling the mussel was as follows:

> Mussel beds were mapped out and coordinate grids were marked out. Each grid intersection was written on pieces of paper. A set of random samples was obtained for population estimates by drawing the papers out and sampling at the intersection. Eleven mussel beds were mapped in Areas A,B, and C. A total of 110 square meter samples were studied, one square meter sample at each intersection chosen by random numbers.

Two species were studied: Mytilus californianus (the mussel)
Pollicipes polymerus (the goose barnacle)

Statistical population estimates were made by use of the following computations (also used by other student investigators):

Sample Estimates

To determine the mean: $\bar{X} = \frac{\sum x_i}{n}$

the variance: $s^2 = \frac{n\sum x_i^2 - \left[\sum(x_i)\right]^2}{n\,(n-1)}$

the standard deviation: $s = \sqrt{s^2}$

Population Estimates

Use of the 95% confidence interval: for the range within which one may expect the true population mean to occur, in 95% of repeated sampling. $P\left(\bar{X} \pm Z_{\frac{\alpha}{2}} \frac{s}{\sqrt{n}}\right) = 1 - \alpha$

The population of Mytilus californianus varied considerably at Duxbury Reef. In Area C, large numbers were counted per square meter. ranging from 456 to 2,022 mussels per square meter sample. Pollicipes polymerus, the goose barnacle. which lives commensally with the mussel ranged from 0 to 338 individuals per square meter sample.

Summary of G. Williams' Calculations

Areas	$\bar{X}$ = mean/m^2		Mussel's 95% confidence interval μ = population mean	Length(cm) Range of Mussels
	Mytilus (mussel)	Pollicipes (barnacle)		
Area A (one bed)	354 (10 samples)	462	-	3-6 cm (1-2½ inches)
Area B (one bed)	335 (10 samples)	0	-	4-8 cm (1½-3½ in.)
Area C (nine beds)	854 (90 samples)	73	$711 \leq \mu \leq 997$	5-15 cm (2-6 inches)

Generalizations concerning the Study of Mussel Population

1. Area C, containing the most sampled beds, contains the greatest number of mussels. Some of the mussel beds run for about 50 meters in solid patches. The mean $(\overline{X})$ of 854 per square meter indicates the density of these mussel beds in Area C.
2. Notice the ratio of mussels to barnacles. In Area C, the mean of mussel to barnacle is 854 to 73. In Area A, the ratio is 354 mussels to 462 barnacles. Area A's sample was taken in the southwest corner, the only spot with some mussel beds. Otherwise, Area A is fairly devoid of mussels in comparison to Areas B and C. Figure 21 to the left indicates the study sample in Area A. There are more barnacles than mussels. The assumption is that individuals have removed all the mussels (for food and bait), leaving the unwanted barnacles by themselves! Normally, these barnacles should be heavily surrounded by the mussels.

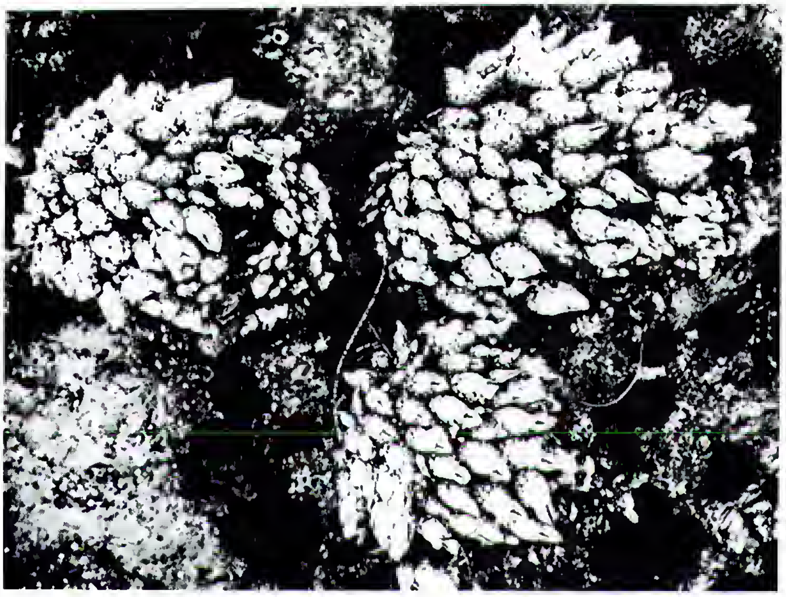

Figure 21. Sample of Area A mussel bed. Pollicipes polymerus, the goose barnacle, dominates the mussel beds.

3. The size of mussels is very conspicuously small in Area A. from 3-6 centimeters (less than 2½ inches). They are larger in Area B, and in the far out reaches of Area C, Section 5, the mussels are huge; some are 15 cm or about 6 inches in length. Obviously, the close in Areas A and B are well picked over by mussel fishermen and collectors. In the outer parts of Area C, where access is difficult, they still remain large and somewhat untouched.
4. In some sections of Areas A,B, and C, there are large glaring open spots where one can easily see that mussels have been scraped off. Since there is no limit as to how many mussels may be taken from the sea shores, it is recommended that the following take place in the

proposed "marine reserve":

a. Fishermen may use mussels for bait, and mussels should be pulled from the center of the beds.

b. Fishermen taking mussels for human consumption should be limited to a fish and game license of 50 mussels per day, with a minimum size of 10 cm or 4 inches. This will enable most of the patches to grow and expand over the years. In fact, this requirement should be a statewide fish and game regulation!

The mussel is quarantined during the summer months because of the collection of undigested marine dinoflagellates on its gills. These are poisonous for human consumption.

5. Mussel beds provide a "city" habitat for over 40 species of animals and plants. These other species may be worth consideration of conservation along with the importance of the mussel beds.
6. If the California population continues in its growth, and more individuals find sport in taking mussels, it would not take much to predict the fate of these organisms on such populated shores as the Duxbury Reef areas.

D. Boring Rock Clams

As already described on previous pages (Fig. 8 and 9, page 13), the rock clammers constitute a hazard, not in the depletion of the boring rock clams, but in the leveling of the shale reef by their use of picks and chisels. This destruction will, in time, along with wave actions, turn the Duxbury Reef profile into a flat-table top reef. Anyone walking through the protective sides of reef areas will notice vast shale destruction from the picks of these rock clammers.

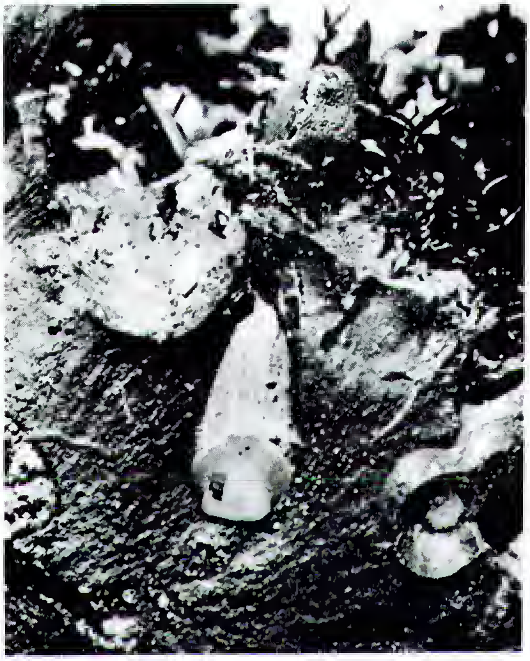

Figure 22. Pholadidea penita, in soft shale.

Student researchers Dennis Peters and Bill Murray were charged with the reponsibilities of determining the major species and population density of the rock boring organisms.

These molluscan bivalves locate themselves in small shale crevices as young larval forms, and in the process of growth and development, they twist and turn in a boring fashion down into the soft shale to build for themselves a nice protective home (Fig. 22). Here they spend the rest of their lives siphoning the planktonic food from the tide-covered reefs.

Some species are shallow borers, in 1-3 inches below the surface (Fig. 22) while others are deep borers, up to 10 inches inside the shale (Fig. 23). It has been reported by some investigators[4] that some species of boring mussels (Botula spp.) secrete an acid which attacks the calcareous rock. we doubt whether such acid-producing glands are of importance at Duxbury Reef, as nearly all the rock is shale and not calcareous; thus, we assume the boring mechanism to be chiefly mechanical, by use of their foot and shell.

The major species of rock clam found at Duxbury are as follows:

Platyodon cancellatus (Fig. 9), the most abundant borer, target of the rock clammers.
Pholadidea penita (Fig. 22), a small boring piddock.
Botula falcata, a boring mussel, very abundant.
Parapholas californica (Fig. 23), the giant boring piddock with a tough calcareous tube, also a choice specimen for the rock clammers.

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[4] Ricketts, p. 231. (3rd Ed.)

There are also a host of bivalve nestlers in shale crevices, belonging to the families Petricolidae and Saxicavidae.

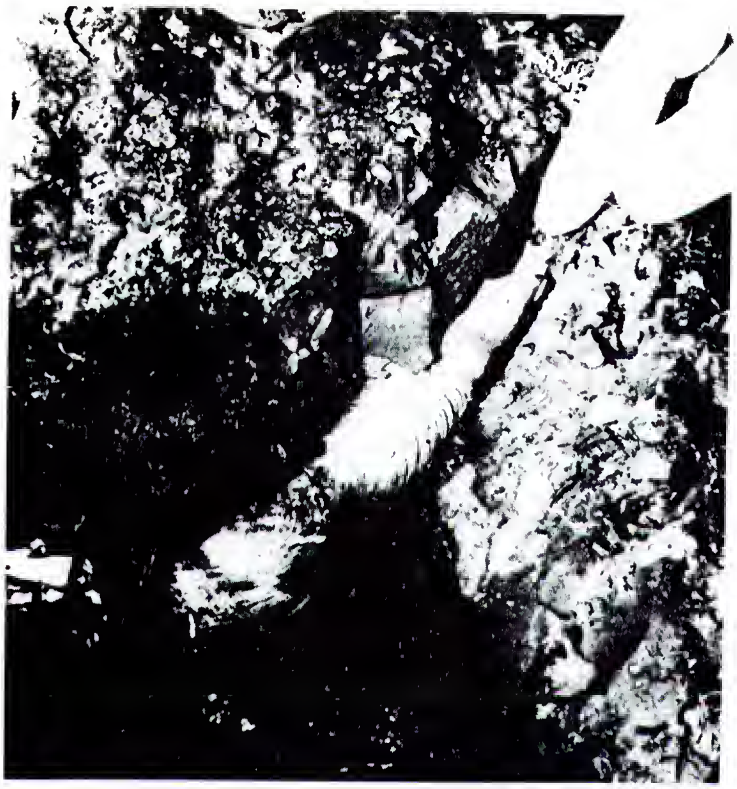


Figure 23. Parapholas californica, the giant boring piddock.

Investigators Peters and Murray utilized a transect methodology of sampling the shale rocks behind the hard rock ridges of the Duxbury Reef areas. At each interval of approximately 25 meters, they dug out an estimated one square foot of rock. Here they counted and identified the species. Converting their sample estimates for a square meter, they obtained a mean, $\bar{X}$, (same statistical formulae as that used for the mussel population). This method was calculated to be important in order to avoid digging more than what was necessary. A total of 38 samples were taken throughout Areas A, B, and C.

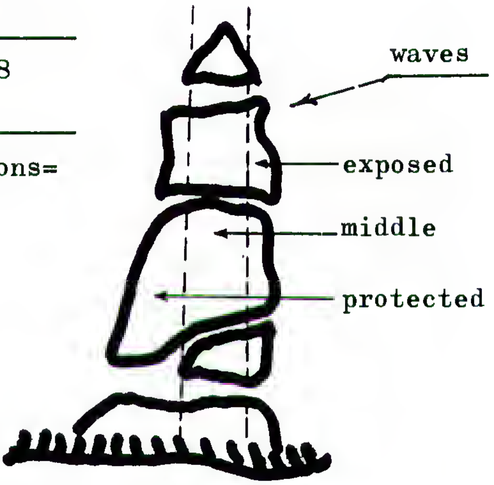
Summary Statistics of borers

	Mean ($\bar{X}$) per square meter		
Areas	Platyodon	Botula	Pholadidea
Area A (8 samples)	17.4	10.6	2.8
Area B (16 samples)	44.6	11.4	22.0
Area C (14 samples)	53.5	85.5	34.8

In Area C, the reef was divided into three regions=

Exposed Side	127#	89
Middle	84	84
Protected	89	95

#These numbers represent total counts of just two species.



Generalizations

1. With consideration of the total 66 acres of the reef, along with the mean number of borers persquare meter, there is evidently a great abundance of these organisms throughout the reef.
2. Area C has the highest density of borers, with no apparent differentiation between the density of borers on the exposed, middle, or protected sides of the reef.
3. If rock clamming is allowed to continue unchecked, we wonder if there will be any correlation between the work of the growing numbers of rock clammers, the impending "flattened" reef, and the probable increased wave erosion of the Bolinas cliffs? Can the residents of the Bolinas headland mesa afford to risk the consequences of ignoring the significance of such a correlation?
4. To repeat the recommendation stated previously, rock clamming should be prohibited in this proposed "marine reserve" in order to protect the shale reef from the destruction caused by the picks and chisels of man. The few rock clammers (average 4 per low tide) should turn their gastronomic interest towards other marine seafoods.

E. Black Turban Snails

As one enters the reef from the Agate Beach entrance to Area A, the first organism usually encountered is the black turban snail, Tegula funebralis (Fig. 24), belonging to the phylum Mollusca.

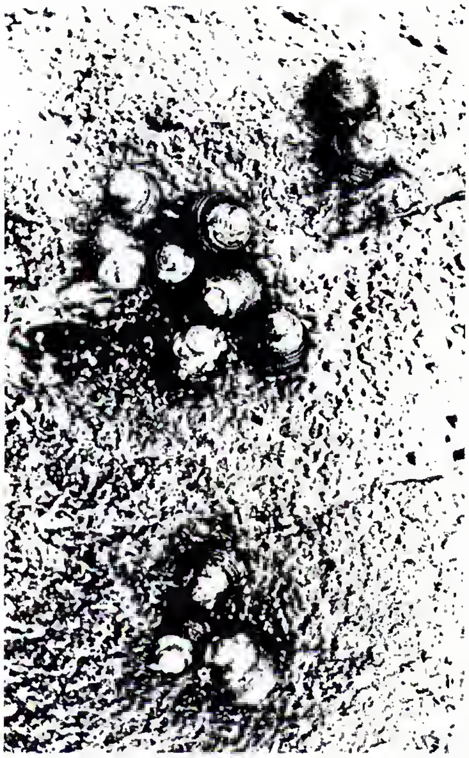


Figure 24. Tegula funebralis, the black turban snail.

There are two major species of Tegula snails on Duxbury Reef, Tegula funebralis, the black turban snail, and Tegula brunnea, the brown turban snail. The black snail is by far the most common.

The investigator, Miss Sara Conklin, found the species to be extremely abundant. Inhabiting the spacious shale flats beyond the low tidal waves, these snails occupy crevices and open flats; in some sections they are so plentiful that they seem to be stacked on top of each other.

Since these snails exist in patches along the shale flats, counting square meters tended to be biased. Miss Conklin's statistics showed the following:

Area	Mean $(\overline{X})$ per m^2
Area A (6 samples)	40
Area B (8 samples)	40
Area C (9 samples)	48

Some Generalities

1. There seem to be hundreds of thousands of these turban snails throughout the Areas A,B,C. There does not seem to be much difference in density of numbers. Some size differences in certain sections may indicate nursuries.
2. Collectors, seeing that these animals are so abundant, do not pick these up to any great extent. The only few people I have seen picking these snails up in large numbers are those intent upon eating them! Thus, man does not seem to be much of a predator on these black turban snails.

F. Sea Slugs

These beautiful multi-colored marine mollusks belonging to the subclass, Opisthobranchia, are the choice prize of students on field trips to Duxbury Reef. The author, listening in on many groups clustered at Duxbury Reef before the charge is given, has heard the leader state, "Be sure to be on the lookout for nudibranchs (sea slugs)". These are snails without a shell in most cases.

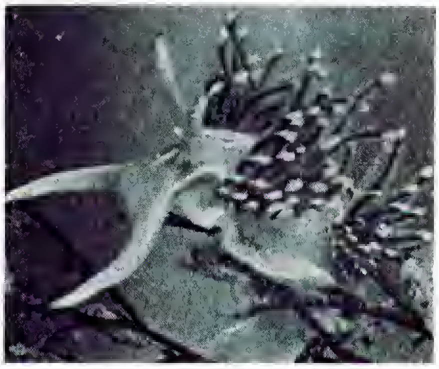


Figure 25. Hermissenda crassicornis, Duxbury's most common sea slug.

These molluscans are commonly found throughout the reef tidepools because of their very bright contrasting colors, a probable mimicry to warn other marine predators to stay away from them. Hermissenda crassicornis, Fig. 25, is by far the most common sea slug found in the reef tidepools, or for that matter, throughout any intertidal region of the Pacific Coast.

The authors have had the pleasure of working with the investigator, Terrance Gosliner, for six years. Mr. Gosliner has worked with the experts in Opisthobranchs and is already considered by the professionals to be one of the outstanding young authorities on the Pacific Coast. His study of "Opisthobranchs of Duxbury Reef and the Bolinas Lagoon" is available for serious researchers into the ecology of the marine organisms. He cites the natural history of these species in his paper.

The species list by Mr. Gosliner (Appendix 2) is one of the first ever for a particular reef, covering a period of three years. The rare species are stated as opinions of Mr. Gosliner. His current research is an attempt to study the habits of these sea slugs; i.e., what do they eat, where do they go in the winter time, are these animals zonated, etc.? The general comment on the density of sea slugs on the reef by Mr. Gosliner is that Area A has the fewest sea slugs-about 5% of the total sea slugs observed, Area B has about 30% (except for Section 3 which is abundant), and Area C has the highest density of these marine animals, about 65% of the total observed.

G. Crabs

Duxbury Reef teems with crabs of all sizes and species. Crabs should be a prime example in illustrating the hypothesis that more visitors to Areas A and B result in less marine organisms. In reality, investigator David Stebbins arrived at a variety of results which are quite interesting.

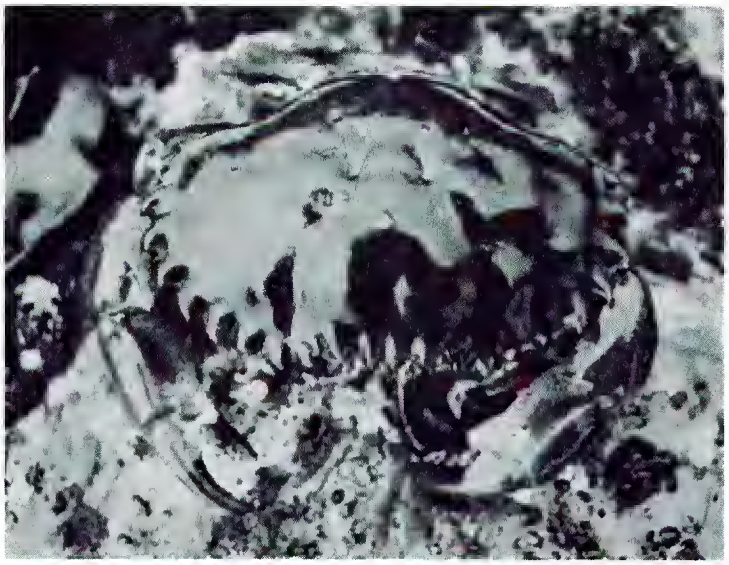


Figure 26. *Cancer antennarius*, large rock crab.

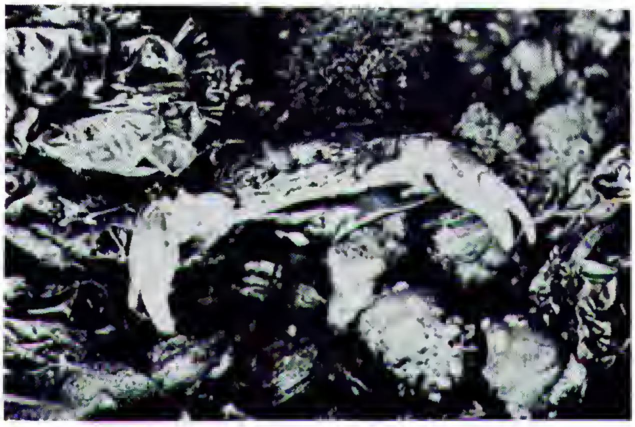


Figure 27. *Pachygrapsus crassipes*, the quick moving lined shore crab.

Mr. Stebbins' methodology of using visual counts on observation trips produced a sample count on four organisms:

Cancer antennarius, the large red rock crab (Fig. 26).

Pachygrapsus crassipes, the fast moving lined shore crab (Fig. 27).

Hemigrapsus nudus, the purple shore crab and close relative to *P. crassipes*.

Petrolisthes cinctipes, the porcelain crab which lives under rocks and mussel beds.

There are no consistent crab fishermen on the reef, as the *C. antennarius* does not grow to large sizes for sufficient take. We suspect that if clam diggers come upon a crab with a 7-inch carapace width, they will stuff it into their clam sack for a small meal at home. Furthermore, school children have some fear of the crabs because of their menacing chelipeds (claws). Chan has seen a *C. antennarius* almost tear a woman's finger off because she carelessly grabbed this muscular crab the wrong way. Many other persons have probably felt this same hurt in some degree when picking up crabs.

David Stebbins' total counts revealed the following:

Areas	*C. antennarius*	*P. crassipes*	*H. nudus*
Area A	0	1	29
Area B	3	311	0
Area C	46	13	0

Generalities

1. The scarcity of C. antennarius may reflect the hypothesis that man is picking up the crab in areas heavily populated with visitors. The other crabs do not show the hypothesis to be true. The answer to this dichotomy comes from understanding the nature of the crabs:
   - C. antennarius is large and very slow moving. He can be trapped and bucketed without much difficulty in his habitat of living in the open shale flats and tidepools.
   - P. crassipes and H. nudus are very fast movers and live in crevices. The high counts in Areas A and B simply show that they are difficult to catch, and indeed they are! The garbage left over by human visitors may further account for the higher numbers of these scavenger-feeding animals.
2. P. cinctipes, the procelain crab which lives under the rocks and mussel beds, appears to be large in numbers. Stebbins' minimum countsof these crabs per square meter in the mussel beds were 1.600±! This number seems quite high, as Hewatt's square meter showed 416 such crabs in his Monterey sample. Nevertheless, it may be assumed that this crab exists in very high numbers throughout the reef.
3. Since these crabs form a vital part of the food web within the reef area, it is recommended that all crabs be protected from being removed. In the authors' own observations,Cancer antennarius seems to be threatened with extinction in Areas A and B; Area C, being more remote, is still somewhat populated with this crab.

H. Sea Stars (Starfish)

If any marine animal is to fully show the validity of the main hypothesis-more people = less animals - it is the Echinoderm sea stars (starfishes) which might best exemplify the assumption. In the establishment of the Moss Beach Reef in San Mateo County as a marine reserve, the absence of sea stars was one of the major illustrations of the intrusion of collectors.

Sea stars feed on mussels, Fig. 28, and in the status of sea stars at Duxbury Reef, the decreased number of stars in Area A (Agate Beach) might be caused by duo forces. Investigator Miss Pamela Blair used the methodology of transect walks, recording sea stars at every 10 paces or approximately 8 meters. At every interval she counted sea stars in a large area, totaling 212 samples in Areas A, B, and C. Her count involved two species of sea stars, Pisaster ochraceous and Pisaster brevespinus. In the statistical counts, the stars are near extinction in Area A.

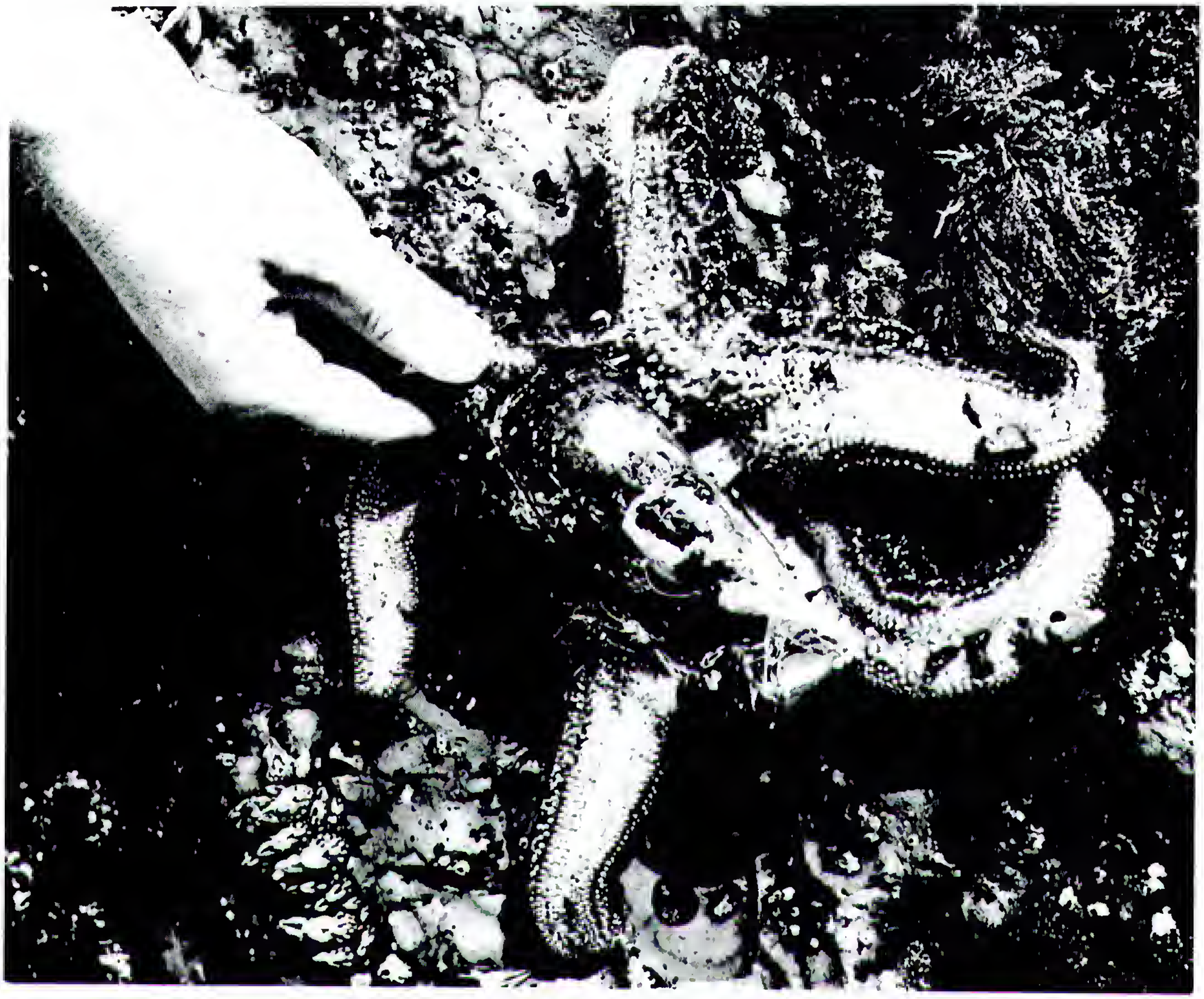


Figure 28. Pisaster ochraceous, the sea star, feeding on its favorite food, the California mussel, Mytilus californianus.

P. Blair's Statistical Summary

Areas	No. of Samples	No. of Pisasters	Chan's Counts 3-day observation
Area A	44	3	3 (all that he could see in one day!)
Area B	128	49	58
Area C	40	55	79
Total	212	107	140

Generalities

1. Area A, according to the observations by Miss Blair and the author each operating on different days, shows a similar substantive count. The causes for the low count in Area A may be attributed to:
    a. People are habitual collectors of sea stars for home trophies. Man is the major contributor to the few remaining stars in Area A.
    b. Since Area A also has the lowest density of mussel beds (Williams' report) and the smallest size of mussels, then there would naturally follow that there is less food for sea stars to eat, thus resulting in a fewer of these echinoderms in Area A.
2. Sea stars from Area B were abundant because the highest density of count was at the outer reaches of Section 3 where few visitors reach. Most individuals search the ridge in Section 2. (See Fig. 3, 3A, pp. 7,8)
3. Sea star sizes in Areas A and B are small in comparison to those at Sect. 4 and 5 in Area C. Few visitors get out to these far sections to take home the giant stars (Fig. 29).
4. Recommendation: All sea stars should be protected, and sea stars should not be carried from their natural habitat of the mussel beds.

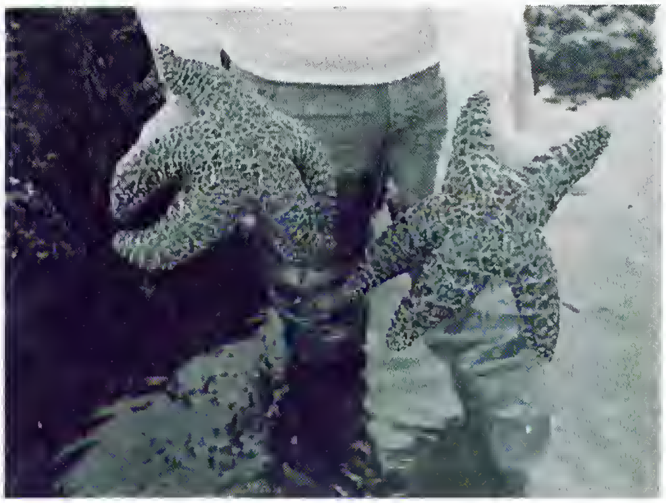


Figure 29. Giant size P. ochraceous from the outer sections of Duxbury Reef, Area C, Summer, 1968.

I. Sea Urchins

The last marine invertebrate surveyed in the summer of 1968 was the purple sea urchin, Strongylocentrotus purpuratus, belonging to the phylum, Echinodermata, the spiny skin animals. In all of the Duxbury Reef Areas, A–C, these sea urchins are located at the zone 4 (very low tide) edge of the wave swept rocks. These algae-eating sea urchins slowly burrow into the soft shale to prevent their being washed away by waves (Fig. 14, 30).

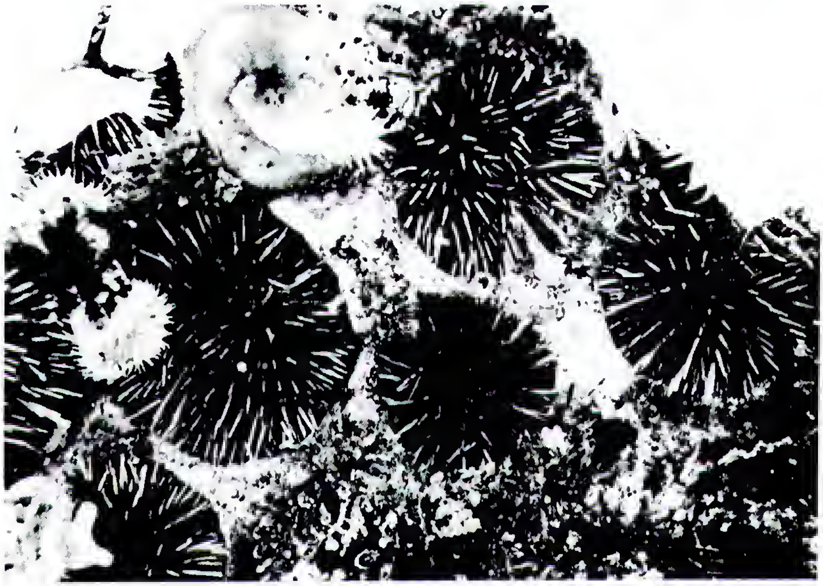


Figure 30. Strongylocentrotus purpuratus in their intertidal burrows.

Research investigators on sea urchins were:

Miss Kit Hermann
Miss Diane Zimmerman

In their research methodology, they surveyed the vertical zone 4 area where the low tide waves meet the rocks. Using transects, they made an interval count every 25 meters along Areas A, B, and C. At each interval, they sampled a one-square-meter plot. Sea urchins cannot tolerate a long exposure time out of the intertidal waters, and thus are more abundant below the low water surface. Skin and SCUBA divers will attest to the abundance of sea urchins on the ocean floor of the continental shelf.

Urchins are basically algae eaters, consuming great quantities of kelp. In Southern California, the kelp industries are battling the urchins with lime (which kills them) and underwater divers swinging hammers in the attempt to reduce urchin population and save the kelp. Predators of the sea urchins in our locality are the sea stars of the previous discussion (Fig. 14, 29) and in particular, the large sun star, Pcynopodia helianthoides.

Like the other investigations, the sea urchin surveys were made on minus low summer tides. The summary calculations were as follows:

Areas	No. of Samples	$\bar{X}/m^2$	Projected Total Urchins	Observations
Area A	3	15.0	1,125	Great number of empty urchin beds
Area B Sec. 1	6	22.2	16.650	Greatest density in Sec. 3.
Sec. 2 & 3	6	29.5	44.250	
Area C	16	19.0	106.720	Greatest density in Sec. 2. 3. and 4. Sec. 5 was not sampled.
			168,745 =	Rough estimate of the projected population at low tides of -0.9 to -1.5.

Generalities

1. Remembering that the intertidal urchins represent but a small proportion of the majority which live in the sub-littoral zone, one may assume that urchins are of vast numbers on and below the intertidal zone. However, since most reef visitors do not dive, the remnant of urchins seen at Duxbury do present an educational experience for reef visitors.
2. Since it was reported in Miss Blair's study that there are few sea stars, we then assume that the many empty urchin holes were not a result of these echinoderms. We may conclude that man again has been the predator in recent years. Some people are known to gather sea urchins for food; the gonads of the urchins are considered to be a gastronomic delicacy. We do not believe, however, that these few gatherers are responsible for the depletion of the urchins at Area A; rather, the large numbers of school children may be the culprits in this echinoderm heist.
3. We recommend that urchins be a protected species in the proposed "marine reserve". The small number of gonad-eating people should really dive for the larger urchins living under the surface, or go into Southern California where sea urchin eaters are most welcomed; in fact, one can be paid for this task by the sea weed industry!

J. Fishes

The 1968 study of fishes on Duxbury Reef was compiled by James Smith, Buz Leuchtenberger and John Worman. Their study concentrated on the swift and small tidepool fishes rather than on the larger sport fishes in the bigger pools. The investigators' chief sampling technique was to drain the tidepools, identify and count the species. In sampling the tidepools throughout the reef areas, A,B, and C, an attempt was made to determine what happens to tidepools depleted of fish. In one test pool in Area C, the investigators removed all the fish and water from the pool, to test their hypothesis that tidepool fish density fluctuates frequently. The test pool contained 16 fish, of both sculpin varieties (15 *Oligocottus snyderi*, Fig. 31, and 1 Oligocottus maculosus). Returning 24 hours later to sample this same pool, the investigators found 21 fish (all *Oligocottus snyderi*), an increase of 5 fish. There seems to be some support for the idea that fish are quite mobile during periods of high tides and tidepools are immediately replenished.

A second question was probed- Do school children deplete the fish population in Area A as compared to Area C which few children visit? Using the same technique of draining the pools, the investigators arrived at the following results:

Areas	Number of Samples-Tidepools	Number of Identified species	Total number of fish	$\bar{X}$, mean/pool
A	5	2	36	7.2
B	6	6	98	16.2
C	4	6	41	10.4
	15		176	11.7

The lower total number (and mean) of fish in Area A may not significantly indicate that the cause is due to people picking up fish for school aquaria. In light of the fact that fish are very mobile during times of high tides, the investigators concluded that perhaps the lack of overall marine organisms in Area A, thus providing less abundance of food, might contribute towards the lower total numbers of fishes. Then, again, the sampling technique might be biased, although tidepools sampled were in areas of heavy foot traffic. In fact, there are probably numerous reasons for the decreased numbers of marine organisms in Area A.

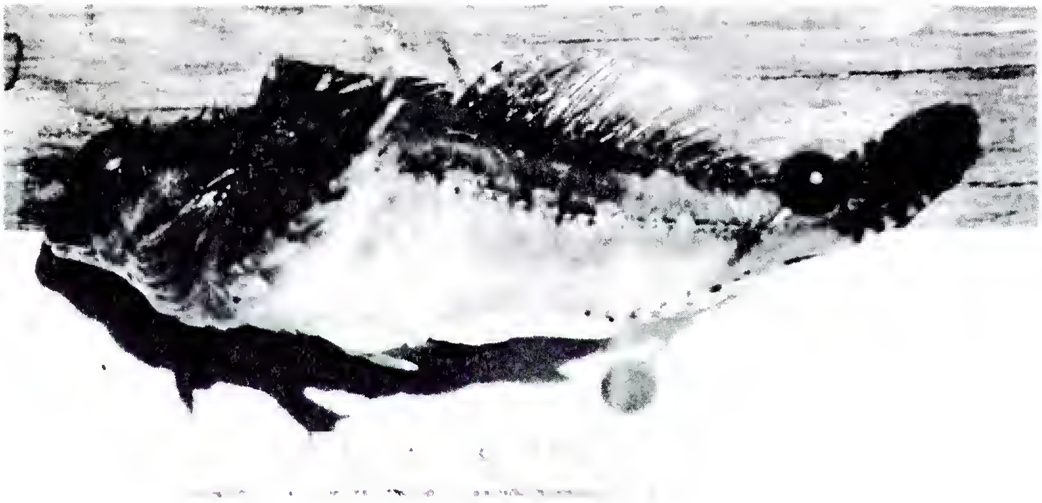


Figure 31. Oligocottus snyderi. The most abundant tidepool fish found in the studies. This small cottid (sculpin) averaged about 6 cm or about 2¼ inches in length.

The above fish was counted as the most abundant fish found in the survey. Of the 176 total number of fish counted, 84% or 148 were O. snyderi. This swift swimming fish also utilizes a clever color adaption to camouflage his body in the tidepools. Its stomach contents yielded almost 100% amphipods.

The species list of the 1968 investigation resulted in the following tidepool fishes:

Species	Number found
Oligocottus snyderi	148
Gobiesox meandrica	7
Clinocottus globiceps	7
Xerepes fucorum	5
Oligocottus maculosus	2
Oligocottus rimensis	2
Anoplarchus purpurescens	1
Clinocottus analis	1
Unidentified cottids	3
	176

Appendix 3 species list cites the work of Dr. Stanley H. Weitzman. In parentheses we have given common names to those fish which are considered game fish by reef fishermen.

Recommendation: Sport fisheries be permitted from Duxbury Reef, subject to California Fish and Game regulations; other collection of tidepool fish be discouraged.

K. Other Marine Organisms

The foregoing discussion of marine organisms was intended to list the major animals most likely to be affected by the population of humans on Duxbury Reef. The following is just a brief review on a few other species somewhat classed as "not major" but important to the reef ecology.

1. The limpet molluscans are a group which probably is one of the most numerous of reef marine organisms. They are found on nearly all exposed rocks. The only species which seems threatened with extinction is the owl limpet, Lottia gigantea (Fig. 32). Throughout the west coast, this large oval limpet, about 2-3" in length, can only be found in "virgin" reef areas or in marine reserves such as Pt. Lobos in Monterey County. These limpets are a delicacy for many individuals, and when spotted are quickly pried off since there are no fish and game limits. At Duxbury Reef, only a very small number, 16, of these animals remain in a well-concealed group of rocks in Area C, Section 3. Again, it is our hope that the revealing of such "secrets" will not lead to an immediate rush or fishermen to deplete these remaining few. These should be left for education rather than digestion!

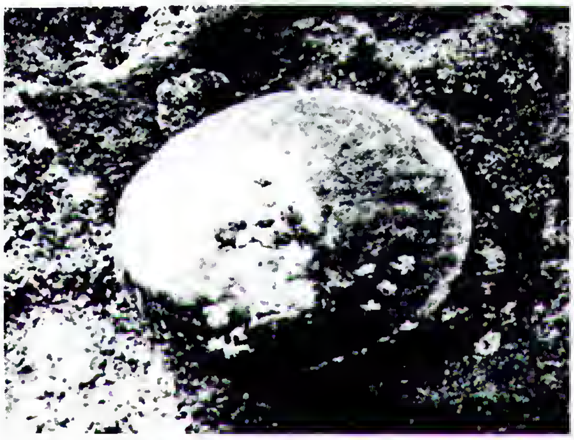


Figure 32. Lottia gigantea, the giant limpet, about $2\frac{1}{2}$" long.

2. Other reef marine organisms such as snails, rock oysters, kelp crabs, shrimps, barnacles, octopus, tunicates, and sea stars, all should be protected from the collecting habits of man. These and many others are so very important to the natural ecology of the total intertidal reef.
3. Lastly, the marine algae constitute a vast mass of organic life which provides food and habitat for countless numbers of marine animals. A study of the intertidal algae at Duxbury by Miss Mary deFremery is available at the Bolinas Marine Station along with many other fine textbooks (see Bibliography). Fortunately, few people pick seaweeds. Here is much beauty for the enjoyment of all who may desire such education. There is no recommendation to prohibit the removal of seaweed from any reef area.

L. Summary of Major Intertidal Marine Animals in Areas A,B, and C of Duxbury Reef

Major Marine Animals	Area A	Area B	Area C	Comments on samples
1. *Anthopleura xanthogrammica* (sea anemone)	32	168	448	Counts made for specific sections in each area.
2. *Mopalia spp.* (chitons)	16	66	79	Counts made from 48 sample intersections.
3. *Mytilus californianus* (mussel)	354	335	854	*$\bar{X}/m^2$
4. *Platyodon cancellatus* (boring clam)	17	45	53	$\bar{X}$ m^2
5. *Haliotis rufescens* (red abalone)	0	0	3	Only 3 abalones were observed intertidally in Area C the past 3 yrs.
6. *Lottia gigantea* (owl limpet)	0	0	16	Total number counted in Area C.
7. *Tegula funebralis* (black turban snail)	40	40	48	$\bar{X}$ m^2
8. Opisthobranchia (sea slugs)	5%	30%	65%	% of total observed by T. Gosliner in a 3-yr period.
9. *Cancer antennarius* (red rock crab)	0	3	46	Total counts in each area.
10. *Piaster ochraceous* (purple sea star)	3	49	55	Total transects counts.
11. *Strongylocentrotus purpuratus* (purple sea urchin)	15	22 Sec.1	29	$\bar{X}$ m^2
12. Cottid (fish)	7.2	16.2	10.4	$\bar{X}$ m^2 for specific tidepools.

* mean or average counts per square meter.

V. CONCLUSION and RECOMMENDATIONS

A. General Considerations

Duxbury Reef is, in the authors' opinions, one of the largest and most richly populated shale reefs on the Pacific Coast. Its marine organisms illustrate beauty and variety of such magnitude that conservation of the reef and its organisms seems to be of utmost importance. To conserve the reef is to allow the natural forces of ecology to interact with time.

The discussion of the major marine animals on the reef omits several related organisms which inhabit the reef areas. For instance, the use of the reef by birds- the American egret, blue heron, pelican, and many other shore birds- is interrelated to the natural ecology of the reef. The occupancy of Section 5 of Area C by a large herd of seals and sea lions is another important factor to consider in the total uniqueness of the reef. One other organism needs to be mentioned. This organism is classified as the world's most primitive vertebrate-like animal. Looking like a marine worm, this species is being studied by zoologists all over the world as the best illustration of the evolutionary sequence from worm to vertebrate. This species is extremely rare on the Pacific Coast; outside of Westport, Washington, Duxbury Reef is the only spot where Chan has ever found living specimens. The name of this animal is Mesoglossus sp.(?)- commonly called an Acorn worm. At one time, one of his students told a university professor about the worm being on Duxbury Reef; subsequently the reef was invaded by hordes of students with buckets to capture this animal for classroom study. Despite this invasion, the worm still flourishes on the reef and Chan is content to only say that it is found in Area C, Section 2, lest there comes another deluge of higher education students.

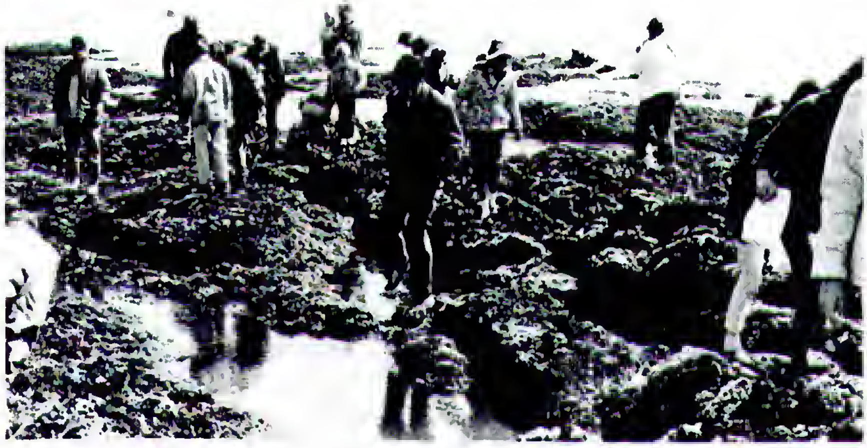


Figure 33. Reef visitors to Area A. Note the lack of collecting buckets.

Those of us promoting the cause of a "marine reserve" at Duxbury do not want the reef to be isolated from people. This great reef should be used, but in proper and conserving fashion. Notice in Fig. 33 that these persons in Area A do not have any collecting buckets. They are here to observe, take notes, pictures and study without removing any marine organisms! Furthermore, the reef should be open to recreational sports fishermen- that is, individuals using the reef for pole fishing of sport fishes (Appendix 3), Figure 34.

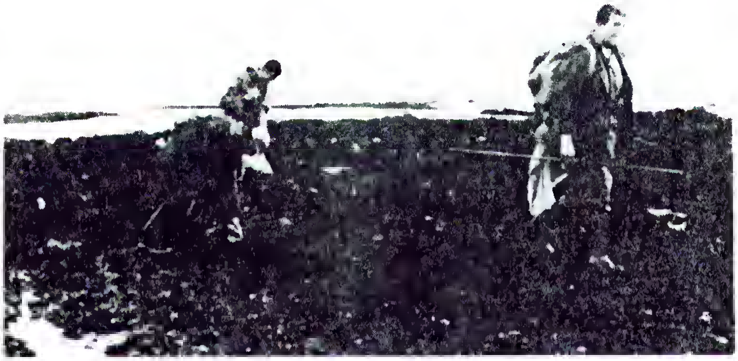


Figure 34. Fishermen on Duxbury Reef, Area C.

In the recommendations to follow, there are suggestions to limit this reef to "fish" fishermen and to prohibit the rock clammer sportsmen from eroding the shale with their picks and chisels. Also, duck hunting from the reef should be restricted as on one occasion, the author and his students were nearly hit by ricocheting bullets.

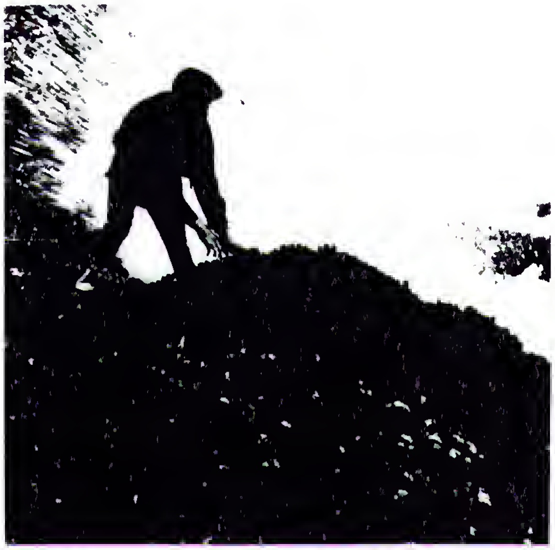


Figure 35. A student nearly hit by a giant wave on Duxbury Reef.

One last word. Though it is recommended that the reef be open to all visitors, groups moving onto Duxbury Reef face the hazard of being trapped by dangerous flooding tidal channels and strong wave actions which can bring disaster to unsuspecting individuals or groups. Occasionally, one reads of individuals being stranded or drowned while adventuring on Duxbury Reef. The ocean is a powerful force and it must be studied and understood to some extent before one attempts to visit these areas. Safety instruction should precede all visits by educational classes; to do otherwise would invite serious consequences and injuries to innocent persons.

A Summary of the Duxbury Reef Areas (Fig. 3 and 3A)

Area A: Agate Beach reef area is the most populated of the reef areas with visitors. The parking lot and road to beach are a convenience for many individuals. However, this area is also most devoid of large marine organisms. Sea stars, rock crabs, large mussels, etc., are nearly extinct from this area.

Area B: This area with its large shale flats and hard shale ridge is being used by more and more institutional students. Some of this area, Sections 1 and 2, are nearly as devoid of large marine animals as Area A. Section 3 of this area is very difficult to reach, and it still is richly populated with these large marine animals- sea stars, etc.

Area C: This long reef, about 1,000 meters in length, is the least visited by humans. Dangerous flood channels and rocks covered by slippery algae prevent many collectors from venturing too far out into this area.

Basic Generalities

1. All three reef areas are basically the same in geological structures and geographically, the conditions for life are similar in all three areas.
2. Although there are many marine organisms still abundant in Area A- e.g.. limpets, turban snails, etc.- it is reported here that Area A seems to have a great lack of large-size marine organisms. See summary table, page 45.
3. The general assumption is that Area A, though smaller in acres than Areas B and C, has been nearly "picked clean" of the major marine animals- sea stars, rock crabs, green sea anemones. mussels, urchins, etc.- by the hundreds of individuals descending onto this reef area from all parts of Northern California.
4. Seeing that Areas A and B are somewhat devoid of major marine animals, students and teachers will become more aggressive and hike out onto the long stretches of Area C, the major reef, for their collecting.
5. Significant reef damage is now occurring through the eroding effects of the picks and chisels of rock clammers.
6. Unless some protective measure, such as the establishment of a "marine reserve", is instituted in the near future, Duxbury Reef will be lost as a beautiful marine habitat. Man has his chance now to contribute to the welfare of the reef and to the education of the increasing future generations of Californians.

B. Specific Recommendations

1. Duxbury Reef, Areas A,B,C, and D should be designated as a "Marine Reserve". Area D, Figures 1 and 7 (pp. 4, 12), the Duxbury sandflats, should be left open for clammers.
2. All marine invertebrates (and the acorn worm) should be protected and restricted from being removed from the reef. The only exceptions are:
   a. *Protothaca staminea*, the butter cockle, can be permitted under Fish and Game regulations to be taken from Area D, the Duxbury sandflats.
   b. *Mytilus californianus*, the California mussel, can be taken, 50 per license-holder per day, with a minimum size of 4 inches in length. These mussels are usually quarantined in the summer months of May, June, July, and August, because of the abundance of poisonous dinoflagellates in these animals during these months.
3. Fishing for all sport fish should be permitted on any portion of the reef. The California mussel is the only marine invertebrate which may be picked up from the reef for use as fish bait. The mussels should be removed from the center of the mussel patches. Collecting of small tidepool cottids should be discouraged.
4. Collecting for scientific purposes can be done only by persons holding the Scientific Collector's Permit as issued yearly to specified individuals affiliated with science organizations by the State of California Department of Fish and Game. (In fact, the total California coast should be regulated by the rules of the Scientific Collector's Permit. That is, no one may collect marine invertebrates unless one holds this permit or one of the annual Fish and Game Sport Fishing Licenses.)
5. Marine algae (seaweeds) may be removed from the reef areas. There is no immediate danger for the extinction of these plants. Man has not yet developed the digestive enzymes whereby he can eat seaweed for beneficial bodily growth- some day, yes, but at present, the seaweeds are just "bulk" foods when eaten. (Minerals can be extracted for beneficial supplements.)
6. The shooting or hunting of all birds from the reef should be prohibited.
7. The jurisdiction of this reserve should be under the auspices of the Marin County Board of Supervisors and its Parks and Recreation Department. A "Reef Patrolman" should be assigned from this department to police the reef at low tides.

8. Suggested timetable for implementation of the "Marine Reserve":

February, 1969-	Proposal initiated by the College of Marin. Proposal reviewed by the County Planning Commission and the Department of Parks and Recreation. Proposal reviewed by the California State Fish and Game, Parks and Recreation, Beaches and Parks Departments.
April, 1969-	Presentation of "Marine Reserve" proposal to the County Board of Supervisors. Public debate of the issues should be held at this time.
May, 1969-	If proposal is passed by the Supervisors, the Parks and Recreation Department should implement signs and rest room facilities in the area, and employ a full or part-time patrolman for the reef. The College of Marin will aid in any development of the Reserve.
June, 1969-	Statewide publication of this Duxbury Reef area as a "Marine Reserve" model.

(The renovation and bulkheading of the eroding Bolinas Headland cliffs may be part of this Duxbury development. Likewise, the hopeful plans of a Bolinas Lagoon Reserve could be eventually incorporated with the reef project to establish in the Bolinas area one of California's most unique marine environments.)

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Figure 31 - by Mr. James Smith
All other photos by Gordon L. Chan, College of Marin

APPENDIX 1. Species List of Animals and Plants Found with *Mytilus californianus*

by Gary Williams
Bolinas Marine Station
July, 1968

Marine Animals

Coelenterata
Anthopleura elegantissima (Brandt, 1835) ***
A. xanthogrammica (Brandt, 1835) **
Tealia crassicornis (Muller, 1776) ***

Annelida
Nereis vexillosa Grube, 1851 *

Arthropoda
Balanus glandula Darwin, 1854 ***
B. tintintabulum (Linnaeus, 1758) *
Pollicipes polymerus (Sowerby, 1833) ***
Idothea stenops (Benedict, 1898) *
Fabia subquadrata Dana, 1851 *
Pachygrapsus crassipes Randall, 1839 **
Pachycheles rudis Stimpson, 1859 (1860) **
Petrolithes cinctipes (Randall, 1839) **
Various species of Amphipods **

Mollusca
Mopalia muscosa (Gould, 1846) **
Kathrina tunicata (Wood, 1815) *
Nuttalina californica (Reeve, 1847) *
Tonicella lineata (Wood, 1815) **
Pholadidea penita (Conrad, 1837) **
Littorina planaxis Philippi, 1847 **
Littorina scutulata Gould, 1849 **
Acanthina spirata (Blainville, 1832) **
Acmaea digitalis Eschscholtz, 1833 ***
Acmaea mitra Eschscholtz, 1833 *
Acmaea scabra (Gould, 1846) ***

Echinodermata
Pisaster ochraceous (Brandt, 1835) **
Strongylocentrotus purpuratus (Stimpson) **

Animal Key (Summer, 1968)

* not common in samples ($0-5/m^2$)

** common in samples ($5-50/m^2$)

*** abundant in samples (more than $50/m^2$)

Marine Plants

Chlorophyta
Cladophora spp. **
Enteromorpha spp. (Linnaeus) ***
Ulva lactuca Linnaeus ***
Ulva taeniata (Setchell(Setchell and Gardner *

Phaeophyta
Egregia menziesii (Turner) Areschoug **
Fucus furcatus C.A. Agardh **
Laminaria spp. *
Nereocystis uetkeana (Mertens) Postels and Ruprecht *
Pelvetia fastigiata (J.G. Agardh) *

Rhodophyta
Bossea spp. **
Endocladia muricata (Postels and Ruprecht) J.G. Agardh ***
Gigartina spp. ***
Halosaccion glandiforme(Gmelin) Ruprecht **
Iridea spp. *
Porphyra perforata J.G. Agardh ***

Seed Plant: *Phyllospadix sp.* **

Plant Key (Summer only)

* not common in samples

** common in samples

*** abundant in samples

Key

* rare, less than two
** few, 2-5
***common, over 5
° Micro sea slug (about 1 cm)

APPENDIX 2. Species List of Duxbury Opisthobranchs 1966 - 1968

by Terrance Gosliner, Bolinas Marine Station

Order: Cephalospidea	
Family: Diaphanidae	1. Diaphana californica Dall, 1919 *
Order: Sacoglossa	
Family: Stiligeridae	2. Hermaeina oliviae MacFarland, new species, 1966 *
Order: Notospidea	
Family Pleurobranchidae	3. Pleurobranchus californicus Dall, 1900 *
Order: Nudibranchia	
Suborder: Doridacea	
Family: Dorididae	
Subfamily: Glossodorinae	4. Cadlina flavomaculata MacFarland, 1905 **
	5. C. luteomarginata MacFarland, 1905 **
	6. C. modesta MacFarland, new species, 1966 ***
Subfamily: Thorunninae	7. Rostanga pulcra MacFarland, 1905 ***
Subfamily: Archidordinae	8. Archidoris montereyensis (Cooper, 1862) ***
Subfamily: Discodoridinae	9. Anisodoris nobilis (MacFarland, 1905) **
	10. Diaulula sandiegensis (Cooper, 1862) ***
	11. Discodoris heathi MacFarland, 1905 **
Family: Notodoridae	12. Aegires albopunctatus MacFarland, 1905 *** °
Family: Polyceridae	13. Laila cockerelli MacFarland, 1905 **
Family: Triophidae	14. Triopha carpenteri (Sterns, 1873) ***
	15. T. maculata MacFarland, 1905 ***
Family: Onchidoridae	16. Acanthodoris lutea MacFarland, 1926 (winter ***)**
	17. A. nanaimoensis MacFarland, 1926 (Summer***) **
	18. A. rhodoceras Cockerell and Eliot, 1905 **
	19. Onchidoris hystricina (Bergh, 1878) ***
Family: Goniodoridae	20. Ancula pacifica MacFarland, 1905 * °
	21. Hopkinsia rosacea MacFarland, 1905 *
Family: Dendrodorididae	22. Dendrodoris fulva (Cooper, 1863) *
	23. Doris sp.? *
Suborder: Dendronotacea	
Family: Dendronotidae	24. Dendronotus albus MacFarland, new species 1966 *
	25. D. frondosus (Ascanius, 1774) **
Family: Dotonidae	26. Doto columbiana O'Donohue, 1927 (Marcus, 1961)*** °
	27. D. wara Marcus, 1961 * °
Suborder: Arminacea	
Family: Dironidae	28. Dirona albolineata Cockerell and Eliot, 1905 *
	29. D. picta Cockerell and Eliot, 1905 ***
Family: Antiopellidae	30. Antiopella barbarensis Cooper, 1863 **
Suborder: Eolidacea	
Family: Coryphellidae	31. Coryphella pricei MacFarland, 1966 **
	32. C. trilineata MacFarland, 1966 ***
Family: Fionidae	33. Precuthona divae MacFarland, 1966 **
Family: Cutonidae	34. Cratena spadix MacFarland, 1966 * °
	35. Catriona albocrusta MacFarland, 1966 ** °
	36. C. abronia MacFarland, 1966 ** °
	37. C. fulgens MacFarland, 1966 ** °
	38. C. lagunae O'Donohue, 1927 ** °
	39. C. ronga Marcus, 1961 ** °
Family: Facelinidae	40 Hermissenda crassicornis (Eschscholtz, 1831) ***
Family: Aeolididae	41. Aeolidia papillosa (Linnaeus, 1761) **
Family: Spurillidae	42. Spurilla oliviae MacFarland, 1966 *

APPENDIX 3. Fish Species List of Duxbury Reef

by Dr. Stanley H. Weitzman, Curator
Division of Fishes
Smithsonian Institution
Washington, D.C.

The following list is based primarily on the results of thirteen collecting trips occurring intermittently between May 1950 and October 1951. Methods of collecting included poisoning with rotenone, seine, dip net, pool drainage and hook and line. Although only thirteen collections were made, some subjective idea of relative abundance of the different species (especially those in the higher tidepools) occurring at Duxbury Reef was obtained.

Three stars (***) indicate the species was found to be very common and may be expected on any trip to the reef. Two stars (**) indicate the species was usually obtained. One star (*) indicates the species was occasionally taken. No stars indicate the species was only rarely obtained. Scientific nomenclature follows Hubbs and Follett's "Manuscript List of the Fishes of California", 65 pp., an unpublished list issued September 5, 1953. Common names, with a few exceptions, also follow Hubbs and Follett's list. All identifications, including those fishes collected by others, have been checked by the author. The names on this list were substantiated by W.I. Follett of the California Academy of Sciences in San Francisco on January 14, 1969.

		Common name
Serranidae		Bass family
1.	*Roccus saxatilis* (Walbaum)	striped bass
Atherinidae		Silversides family
2.	*Atherinops affinis* (Ayres) (taken in large numbers in February 1951)	topsmelt
Embiotocidae		Perch family
3.	*Holconotus rhodoterus* Agassiz *	redtail surfperch
4.	*Hyperprosopon ellipticum* (Gibbons) *	silver surfperch
5.	*Hyperprosopon argenteum* (Gibbons) *	walleye surfperch
6.	*Embiotoca jacksoni* Agassiz *	black perch
7.	*Taeniotoca lateralis* (Agassiz) **	striped seaperch
8.	*Hypsurus caryi* (Agassiz) *	rainbow seaperch
9.	*Phanerodon furcatus* Girard *	white seaperch
10.	*Damalichthys vacca* Girard *	pile perch
11.	*Rhacochilus toxotes* Agassiz **	rubberlip perch
12.	*Cymatogaster aggregata* Gibbons	shiner perch
13.	*Amphigonopterus aurora* (Jordan and Gilbert) *	reef perch
14.	*Micrometrus minimus* (Gibbons) ***	dwarf perch
Scorpaenidae		Rockfish family
15.	*Sebastodes melanops* (Girard) (young, common in August)	black rockfish
16.	*Sebastodes rastrelliger* (Jordan and Gilbert)***	grass rockfish
Hexagrammidae		Greenling family
17.	*Hexagrammos decagrammus* (Pallas) **	greenling seatrout
18.	*Hexagrammos superciliosus* (Pallas) **	rock greenling

Ophiodontidae ------------------------------------ Lingcod family

19. Ophiodon elongatus Girard * ----------- lingcod

Cottidae ------------------------------------ Sculpin family

20. Scorpaenichthys marmoratus (Ayres) *** ----- cabezon
21. Hemilepidotus spinosus (Ayres) * --------- reef Irish lord
22. Artedius harringtoni (Starks) ---------- scalyhead sculpin
23. Artedius notospilotus Girard * -------- bonyhead sculpin
24. Artedius fenestralis (Jordan and Gilbert) --- padded sculpin
25. Artedius lateralis (Girard) ** ---------- smoothhead sculpin
26. Oligocottus maculosus Girard ** --------- johnny sculpin
27. Oligocottus rimensis (Greeley) --------- saddleback sculpin
    (collector Dr. Daniel M. Cohen)
28. Oligocottus snyderi Greely *** -------- chameleon sculpin
29. Clinocottus analis Girard ** ---------- wooly sculpin
30. Clinocottus globiceps (Girard) ** -------- mosshead sculpin
31. Clinocottus acuticeps (Gilbert) * -------- sharpnose sculpin
32. Ascelichthys rhodorus Jordan and Gilbert --- rubber sculpin
33. Enophrys bison (Girard) ** ------------ buffalo sculpin
34. Leptocottus armatus armatus Girard ------- northern staghorn sculpin

Liparididae ------------------------------------ Snailfish family

35. Liparis florae (Jordan and Starks) ** ----- tidepool snailfish
36. Liparis rutteri (Gilbert and Snyder) ------ bandtail snailfish
    (collector Dr. Paul Needham, April 7, 1956,
    University of California)

Gobiesocidae ------------------------------------ Clingfish family

37. Gobiesox maeandricus (Girard) ** -------- northern clingfish

Clinidae ------------------------------------ Klipfish family

38. Gibbonsia metzi Hubbs ** ------------ weed klipfish

Cebidichthyidae ------------------------------------ Monkeyface eelblenny family

39. Cebidichthys violaceus (Girard) ** -------- monkeyface blenny

Stichaeidae ------------------------------------ Prickleback family

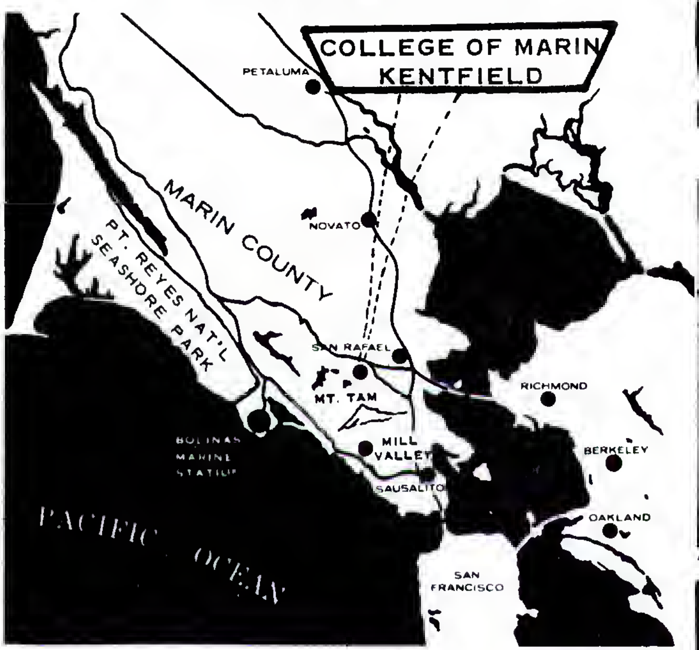
40. Anoplarchus purpurescens Gill ** -------- cockscomb
41. Xiphister mucosus (Girard) *** ---------- rock blenny
42. Epigeichthys atropurpureus (Kittlitz) *** --- black prickleback

Pholididae ------------------------------------ Gunnel family

43. Pholis ornata (Girard) -------------- saddleback gunnel
44. Apodichthys flavidus Girard *** --------- penpoint gunnel
45. Xererpes fucorum (Jordan and Gilbert) *** --- rockweed gunnel

APPENDIX 4.

BOLINAS MARINE STATION

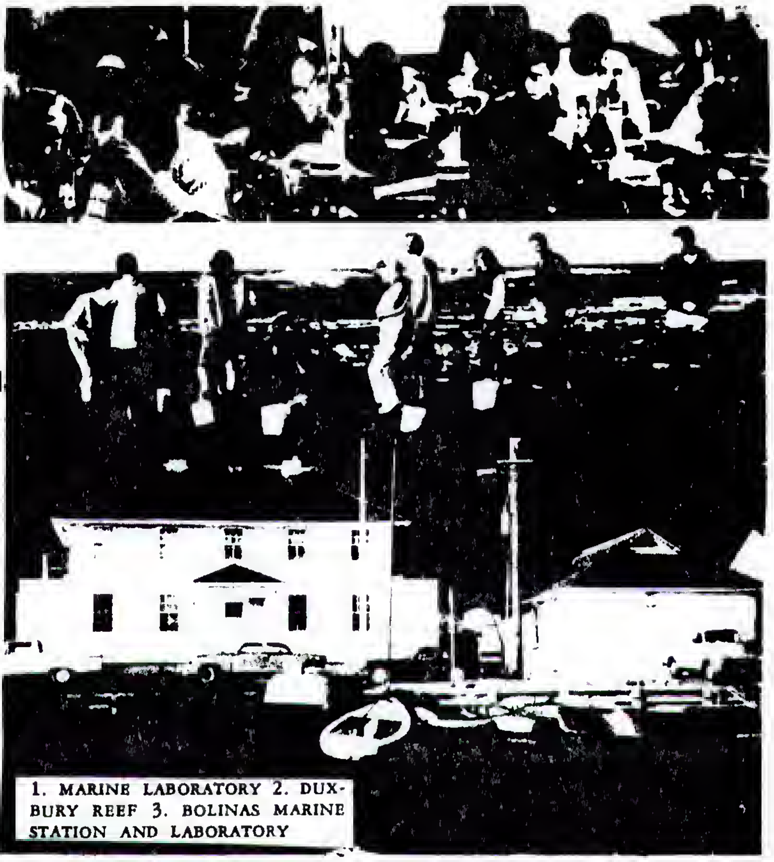


Facilities

Classroom and laboratory study is conducted at the College of Marin's Bolinas Marine Station. This marine laboratory is situated in the ocean-side community of Bolinas, California 22 miles north of San Francisco, and 30 miles from the college main campus at Kentfield. The Marine station complex includes a marine laboratory equipped with 20 student stations.

A circulating sea water system supplies laboratory aquaria for instructional research purposes. Adjoining the laboratory is a two story station house with a marine library, research rooms and offices, sleeping quarters and kitchen for overnight field trips.

OCEANOGRAPHY STUDIES



1. MARINE LABORATORY 2. DUXBURY REEF 3. BOLINAS MARINE STATION AND LABORATORY

Ecological Studies Areas

Within one mile of the Bolinas station are some of the most outstanding marine intertidal regions of the Pacific Coast. This headland region offers acres of shale reefs with an abundance of invertebrate organisms. The "front yard" of the marine station is the famous Bolinas Lagoon with its massive marshes, mudflats, and bird sanctuary. The station also has two Boston whalers and a 32-foot Diesel boat for shallow and deep water studies. Marine investigations are conducted the year around by class groups and by individuals working on research projects.

GROUP FISH STUDIES & INDEPENDENT STUDIES ON A BASKING SHARK

Tide Pools Marine Life in Danger

from the:
Bay & Delta YACHTSMAN
January 1969, pp.4,38

Reprinted from OUTDOOR CALIFORNIA

By RAY CHAPMAN, Editor

The fascinating marine animals that thrive in the tide pools along California's 1,200 miles of coastline are in dire danger of being studied to death.

Increasing numbers of tourists and students, laden with buckets, jars, and plastic bags, are swarming over the state's beaches by the thousands, collecting everything in sight. Many tide pool areas, formerly rich in marine life, have been denuded to the extent that collectors no longer go there, but seek greener pastures that have not yet succumbed to the bucket brigade. This, of course, accelerates their rate of depletion.

The tide pools are rocky pockets that trap water when the tide goes out. Here, and in the intertidal zone (the area between the high and low watermarks) is found an unimaginable diversity of marine life, equal in variety to all the marine life found in the ocean. Rich in oxygen and providing a bountiful food supply, the intertidal zone supports many species of seaweeds, barnacles, anemones, sponges, jellyfish, worms, snails, sea slugs, clams, oysters, scallops, chitons, squid, octopi, abalones, periwinkles, limpets, mussels, cockles, shrimp, crab, starfish, sand dollars, sea urchins, and fish.

It is in the tide pools that the blind goby spends its entire life. A beautiful pink in color and about the size of your index counted 12 busloads of students (30 per bus), collecting specimens. Three days later, there were another 12 busloads (30 per bus) plus 12 college students, all collecting. At this rate, it is only a matter of time until the only living at Moss Beach will be the collectors. Then they, too, will disappear.

A DFG captain reporting on Monterey County, said collecting already has seriously depleted some beach and tidal areas and that complaints from the public on this subject are numerous.

He described groups of students who turn over every loose rock in the area and leave it upside down, with little or no regard for the welfare of the marine organisms. He reported that some students pick up several of each species, take them from the beach, and dump them in the parking lot before they leave.

Because of private ownership and access problems, only one mile of Monterey County's 60 miles of coastline is open to tide pool collectors. This concentration of activity leads to the rapid depletion of marine life.

The Pacific Marine Station at Dillon's Beach reports thousands of student collectors arriving at Bodega, Tomales, and Bolinas by car caravan and buses. Threatened depletion prompted the director of the station, Dr. Edmund H. Smith, to include the proper use of study areas in the marine environment as part of a summer program for teachers and students.

One of DFG's top biologists reported that the method of taking piddocks in tide pools is particularly destructive. Picks and mattocks are used to break the shale outcroppings where the piddocks burrow, and large areas are being dug away and thus permanently destroyed.

TOMALES BAY SWAMPED

Flights by state aircraft revealed a total of 59 buses parked at access areas from Tomales Bay to Natural Bridges State Park, and there were large groups of collectors at several locations where no buses were found.

And it was further reported that on Orange County beaches collectors are at work an average of two days a week and every day during low tides. A college professor reported seeing 15 buses disgorge children, each child with a collecting bucket, and on many occasions, groups of 200 to 400 children have been observed collecting at one time.

Reporting on collecting on San Mateo County beaches, a warden said the pressure on marine life is extremely heavy.

Another concern the warden voiced was over the amount of marine life wasted. Many of the specimens collected are not utilized in any way, he reported, except for a few seconds of observation when they are first picked up, and a few more seconds of observation when the animals have died and are disposed of.

In southern California, the principal collecting areas are Palos Verdes, Corona del Mar, Laguna Beach, Dana Point, and La Jolla. A regional manager reported groups from colleges and universities are observed on all these areas about twice a week except during very low tides when they collect daily. Groups range in size from 10 to 50 persons.

And so on, ad infinitum.

DEPLORABLE WASTE

The waste of marine life by unthinking persons is, of course, deplorable. But even the legitimate uses of collecting for scientific and educational purposes can seriously deplete marine species in tide pools, if collecting is not carefully regulated. The question is, how should this be regulated?

At present, no single agency is responsible for the regulation of overall collecting, although the Department of Fish and Game is responsible for the living resources of the sea.

The Fish and Game Commission has the authority to set seasons, size limits, and bag limits on some species, and scientists who collect protected species must obtain a scientific collector's permit from the Department of Fish and Game.

This leaves the regulation of collecting a divided responsibility between the Department of Fish and Game and landowners, which include the Department of Parks and Recreation, various federal agencies, and private landowners, each of whom controls access.

Is there an answer, and, if so, what is it?

There are several possible answers, and the Departments of Fish and Game and Parks and Recreation are presently working out recommendations for the solution.

One suggestion being looked into is the establishment of marine reserves where collecting would be prohibited. But all areas could not be closed because it would be unfair to the legitimate collector. Another would be enabling legislation that would give a state agency the authority to regulate all collecting. A third would be legislation that would set up regulations to control collecting of all species, by law, rather than assigning a regulatory agency. Another alternative, which would alleviate the problem but would not completely solve it, is to work out a program with the Department of Education to train teachers in proper collecting philosophy and techniques. All these are being looked into.

WHAT TO DO?

Meanwhile, what can be done in the interim? First, those who must collect for scientific or educational purposes should do so sensibly. Take only what you need, and return all unneeded animals to the water. Second, the bucket brigade of grammar school and high school students whose chief motive is curiosity should not collect marine animals. They should return the animals to the water or rocks when the students' curiosity is satisfied. Overturned rocks should be replaced in their original position.

Third, before going on a collecting excursion, check with the Department of Fish and Game. Offices are located throughout the state. Fourth, always check with the landowner or administering agency of the land where you plan to go. Fifth, fishermen searching the rocks in tide pools for bait would do better to buy their bait in a store. If the bait search is deemed necessary, be careful to replace rocks in their original position.

The State Department of Parks and Recreation has expressed its concern over the problem by issuing a policy statement to all its employees, asking them to begin an immediate public education program lr. state parks, highlighting the following points:

"Encourage teachers and their students to observe the animals, photograph them, sketch them, study them, and replace them in their natural habitat in the immediate area where they are obtained. The teacher should take only a minimal number of specimens (those which may be legally removed) necessary for classroom instruction, and should preserve them if at all possible so that future collection may be unnecessary.

"Urge park visitors to make it a point to leave the area exactly as it was when they entered so that the next person may see and enjoy."

On the positive side of the ledger is the fact that the tide pools might have a chance to recover in a period of 5 to 10 years provided they are given some sort of relief from the current onslaught. If those who are collecting marine specimens would reduce their efforts to the absolute minimum necessary for scientific and educational endeavors, the marine resource will have a chance to come back. But at the current rate of use, plus anticipated acceleration if the trend is not reversed, all the state's tide pools will one day be devoid of marine life. This will service no one.

So we have a choice. Be sensible now, or do without in the near future.